New Scientist

WEEKLY 29 June 2024

IMMUNE TO CORONAVIRUS
We finally know why some people don't get covid-19

QUANTUM QUIRK
How to create energy from nothing

APE APOTHECARY
Sick chimps choose plants to heal themselves

SPECIAL ISSUE

OUR COSMIC PERSPECTIVE

The biggest questions about the universe and our place in it

IS THE UNIVERSE INFINITE? / WHERE DO SPACE AND TIME COME FROM? /
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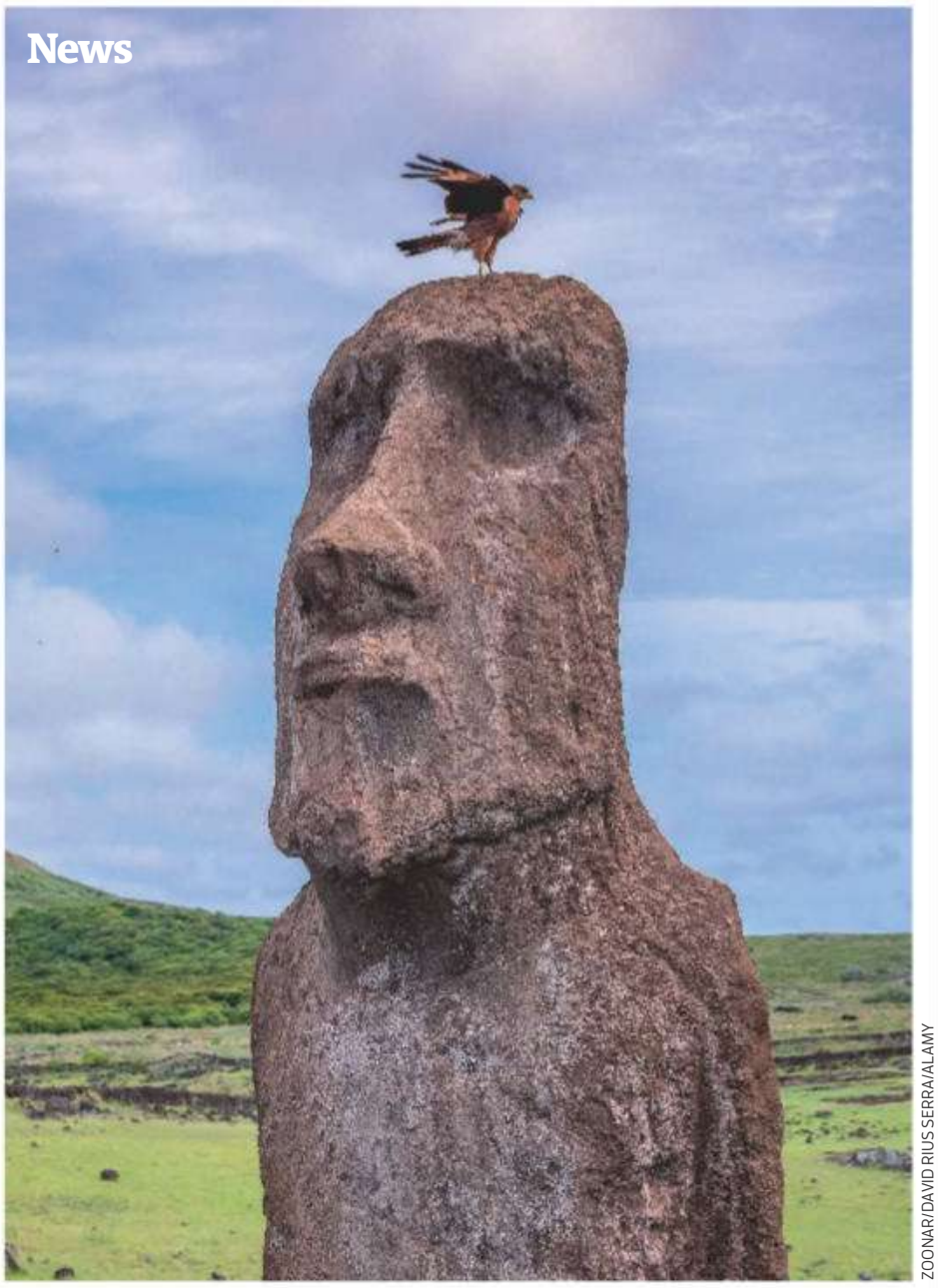

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NS Live

A galaxy far, far away

On 12 October, astrophysicist Or Graur will describe the way we first learned of the existence of galaxies in records made nearly 2000 years ago. Find out how we realised that they are objects separate and far away from the Milky Way, and how they were used to infer the existence of dark matter and to give us insights into the expansion of the universe.

newscientist.com/nslmag

Tour

Machu Picchu and Incan science: Peru

Immerse yourself in the Inca civilisation's most important archaeological sites with anthropologist, film-maker and mountaineer Peter Getzels. Peru is a stunning land of deserts etched with ancient geoglyphs, soaring peaks harbouring secret cities and many other stunning landscapes. This 10-day tour begins on 17 September and costs £3599.

newscientist.com/tours

Podcast

CultureLab

Science and medicine attempt to be unbiased, unaffected by social constructs. Yet we see evidence to the contrary every day, ranging from the false-yet-persistent claim that Black people's bones are denser to the reality that the covid-19 pandemic disproportionately affected people of colour. In this episode, science journalist Layal Liverpool discusses how race and racism infiltrate every aspect of health.

newscientist.com/nspod

VILLE PALONEN/ALAMY

Galactic origins These vast, distant objects underpin cosmology

NASA, ESA, CSA, STScI, ALBERTO BOLATTO (UMD)

Heart of the Incas Walk through cloud forests into the Sacred Valley

Video

New Scientist Book Club

Martha Wells is the author of *All Systems Red*, the first novella in her Murderbot Diaries series. It follows the adventures of a sentient machine intelligence that hacks the system supposed to be controlling it, then discovers that what it really enjoys is watching TV. Wells talks to *New Scientist*'s Sophie Bushwick about how she came up with the idea for the stories.

youtube.com/newscientist

Newsletter

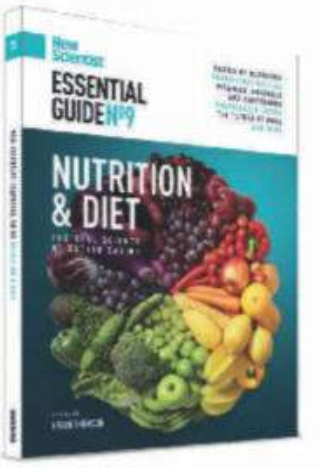
Fix the Planet

The fashion industry is harming the planet in so many ways, but a wave of start-ups could transform how clothes are made for the better. James Dinneen considers three of the brightest ideas on show at an exhibition in London: 3D weaving technology, AI-designed fibres and leather made from waste fish scales.

newscientist.com/fix

Newsletter

"Synthetic fibres tend to rely on fossil fuels for production and shed tiny bits of plastic"



Essential guide

One of our most popular *Essential Guides* is now back in stock. This ninth instalment, *Nutrition & Diet*, delves into the latest research into topics including sustainable eating and the future of food. It asks: why is eating healthily such a problem? Discover the full range now in our online shop.

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Help save the gibbons and win some incredible prizes!

Build THE Change

ENTRY DEADLINE EXTENDED TO 14 JULY

The deadline for the *New Scientist* and the LEGO Group's social impact program competition has been extended to 14 July 2024, giving you more time to come-up with a fantastic idea to help the gibbons navigate their fragmented habitats! Can you design bridges between tree gaps or find innovative ways to help gibbons find their mates through song? Or do you have another idea to help gibbons navigate the threats they are facing.

Finalists will get to work with LEGO® Master Builders to build their solution at New Scientist Live, and their ideas will inspire a real-life invention built by engineers at Imperial College London. The winners will be announced at the New Scientist Live, 12-14 October at ExCeL London.

Join the competition and use this extra time to perfect your ideas!
The competition is open to UK residents* aged 11-14 and includes two categories: i) Schools and ii) General public.

Find out more

newscientist.com/gibbons-competition

*Except residents from Northern Ireland. Please see newscientist.com/gibbons-competition for full terms and conditions

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Do look up

Getting to grips with our place in the universe can offer a grand source of comfort

IN HIS 1980 book *The Restaurant At the End of the Universe*, Douglas Adams imagined a torture device called the Total Perspective Vortex that would subject its victims to "just one momentary glimpse of the entire unimaginable infinity of creation". The result? Instant death.

His invention was a send-up of the idea that contemplating the staggering vastness of the universe inevitably induces existential dread. But as we discover in our special issue, which celebrates the centennial of Edwin Hubble's discovery that ours is not the only galaxy, there is no need to fear the cosmic perspective. In fact, there are good reasons to reckon with our place in the grandest scheme of things.

The first is that getting to grips with the scale of the universe (see page 31) and the mysteries it contains – from the origins of space and time (page 32) to the prospects for life elsewhere and multiple universes (pages 33 and 39) – is awe-inspiring. Like any epic vista, it offers a way to transcend the self, which has been shown to reduce stress and enhance our sense of connection with others. Besides, confronting our cosmic insignificance is arguably a source of comfort anyway, since it reminds us that nothing we do really matters much at all (see page 36).

"There are good reasons to reckon with our place in the grandest scheme of things"

Above all, though, to take the cosmic perspective is to marvel at the fact that we can. Observable matter makes up just 5 per cent of the universe, of which our eyes can only perceive a small fraction. And yet, thanks to our intelligence and ingenuity, we have been able to fathom so much about the cosmos, from the epic tale of its origins and evolution over 13.8 billion years to the often-strange properties of the particles and forces that comprise it.

Now we are beginning to reckon with the things we do not and cannot know, not least with the realisation that there is no objective view of the universe. As a result, we are reimagining our place yet again by rethinking the relationship between mind and matter (see pages 37 and 38). If this is what a Total Perspective Vortex really looks like, it is anything but torturous. ▮

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Discovery Tours

NewScientist

The science of rewilding: Coombeshead, Devon

16 August 2024 | 3 days from £749 per person

Discover how nature is making a comeback in the scenic Devon countryside. This weekend break has been designed to reconnect you with nature and is perfect for anyone looking for an immersive experience in the heart of the beautiful, wild Devon countryside. Learn about how rewilding is becoming a global phenomenon, the history of rewilding, and all about the native species that are being reintroduced to the British countryside.

Witness the project's 'rewilding helpers' such as beavers, water buffalo, wild boar, mouflon sheep and Exmoor ponies in action, with Dartmoor and Bodmin Moor as your beautiful backdrops. Hosted by *New Scientist* feature writer, Graham Lawton, along with a carefully curated selection of leading ecology, conservation and natural world experts who will offer insightful talks throughout the weekend.

Accommodation options:

Choose to stay in a luxury bell tent, 4 star traditional farm cottage or bring your own tent to pitch in a beautiful meadow between the farm and the main rewilding area.

Highlights include:

- **Hear talks from *New Scientist*'s Graham Lawton and conservationist, Derek Gow, the owner and driving force behind Coombeshead, plus several leading rewilding, conservation and nature experts.**
- **Enjoy a walking safari where you will see rewilding helpers such as the beavers, wild ponies, boar and water buffalo, and appreciate the differences they have already made to the landscape.**
- **Discover the breeding and reintroduction programme where you will see some of the amazing species at the centre including white storks and water voles, and harvest mice. Finally, visit to the wildcat breeding area, where hopefully, you will get a glimpse of these elusive cats and maybe even their kittens.**
- **Rise at dawn and go beaver-watching* in a hide, led by one of the site ecologists. Where you will learn about the ecology of the beaver and how and why it has engineered the wetlands at Coombeshead.**

Scan me to find out more

Find out more at

newscientist.com/rewilding-weekender

*There is an additional charge for beaver-watching.

News

Disappearing act
Did Jupiter's Great Red Spot vanish and reform? p8

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Triceratops relative had giant frilled skull p10

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Walk in the park
Taking a stroll helps keep people free of lower back pain p15

Leaping leeches
Bloodsucker jumps by coiling its body like a cobra p18

Astronomy

The stars align for cosmologists

These fiery jets of material (see the orange blobs angled from top left to bottom right) are coming from baby stars in the Serpens Nebula, about 1300 light years away. This image from the James Webb Space Telescope proves an idea that had long been assumed but never observed: as spinning clouds of gas collapse to form stars, the stars tend to spin the same way, with their jets pointing in roughly the same direction.

NASA, ESA, CSA, STSCI, K. PONTOPPIDAN/JPL/A. PAGAN (STSCI)

Astronomy

The youthful face of Jupiter?

An Earth-sized storm on Jupiter known as the Great Red Spot may be a recent addition

Leah Crane

JUPITER'S Great Red Spot could be younger than many astronomers thought. It is commonly accepted that the enormous storm was first observed by Giovanni Cassini in 1665, but it turns out that the spot he saw was probably different to the vortex visible now.

The spot, a storm larger than Earth, has been continuously observable since 1831. But an enormous storm was also visible at the same location on Jupiter from 1665 to 1713, and astronomers have been debating whether the two tempests are in fact one and the same for decades.

Agustín Sánchez-Lavega at the University of the Basque Country in Spain and his colleagues performed a systematic review and analysis of all the available observations of the earlier storm – which was known as the Permanent Spot – preserved in astronomers' drawings.

They then compared them to early photographs and newer images of the Great Red Spot we see today. They found that, if the drawings are accurate, the Permanent Spot was far smaller than the Great Red Spot – its diameter would have had to grow at a rate of about 160 kilometres per year from 1713 to 1879 for the two to be consistent.

But none of Jupiter's vortices have been shown to grow in such a rapid and sustained manner. Moreover, recent observations show that the Great Red Spot appears to be shrinking, not growing. This and other factors, along with the 118-year gap in observations, led the researchers to conclude that the two spots aren't the same (*Geophysical Research Letters*, doi.org/m446).

Jupiter's red spot as captured by NASA's Juno spacecraft

NASA/JPL-CALTECH/SWRI/MSSS/GERALD EICHSTADT/SEAN DORAN/CC NC SA

However, Scott Bolton at the Southwest Research Institute in Texas says it is difficult to make secure conclusions based on hand-drawn pictures of a distant world.

"What I think we may be seeing is not so much that the storm went away and then a new one came in almost the same place – it would be a very big coincidence to have it occur at the same exact latitude, or even a similar latitude," he says. "It could be that what we're really watching is the evolution of the storm." That still wouldn't account for the recent shrinking, though.

Even if the Great Red Spot is younger than we thought, it is still far longer-lasting than any other storm we have ever seen. But if it isn't, it could be mind-bogglingly old. "If this was actually the same storm that Cassini saw, even in a different form, it could be much older than the 1600s," says Bolton.

On the other hand, if the two spots seen on Jupiter are wholly different storms, "an implication... is that the modern Great Red Spot must have formed or appeared during the late 18th century or just after," says Peter Read at the University of Oxford. "Its formation may therefore have been amenable to observation, at least in principle."

If that is the case, we could search for hints of the birth of the Great Red Spot in the historical record, closing the case of the two spots once and for all. ▮

Archaeology

World's oldest wine found in 2000-year-old Roman tomb

A REDDISH liquid found in an ancient Roman mausoleum in Spain is the oldest known liquid wine in existence, a chemical analysis has revealed.

"It seemed impossible that a liquid could have remained in this state for 2000 years," says José Rafael Ruiz Arrebola at the University of Cordoba in Spain.

Until now, a sealed vessel found near Speyer, Germany, and believed to be about 1700 years old, was thought to contain the oldest known wine, but it has never been opened.

The Spanish tomb, discovered in 2019 in Carmona, near Seville, dates from the 1st century AD and belonged to a wealthy family. Burial niches carved in its walls held six urns made from limestone, sandstone or glass. Half contained the cremated remains of women and the other half those of men. Two urns bore the names of the deceased: Hispanae and Senicio.

One of the glass urns, encased in a lead shell, contained bone remnants of a 45-year-old man, a gold ring bearing the image of the two-faced Roman god Janus and approximately 5 litres of liquid.

Ruiz Arrebola and his team studied the composition of the reddish liquid by methods including liquid chromatography-mass spectrometry.

Its mineral profile was similar to that of modern sherry and fino wines from Spain. It also contained seven polyphenols, natural antioxidant compounds, exclusively found in wine. The absence of syringic acid, a compound produced when the main pigment in red wines decomposes, confirmed the fluid was white wine. It had a pH of 7.5 – more alkaline than normal for wine, indicating strong decay. The wine was probably meant for the deceased to drink on the voyage into the afterlife (*Journal of Archaeological Science: Reports*, doi.org/m45g).

> "It seemed impossible that a liquid could have remained in this state for 2000 years"

The find provides unique insights into Roman burial practices, says Davide Tanasi at the University of South Florida. ▮

Soumya Sagar

Environment

Overheated trees are contributing to urban air pollution

James Dinneen

AIR pollution in Los Angeles from cars and human activity is getting a boost from the city's plants, some of which emit chemicals in response to rising temperatures and drought.

"Since it's hard to control the plant emissions, it's even more important to control the [human-caused] part," says Eva Pfannerstill at Forschungszentrum Jülich, a research institute in Germany.

Many plants emit a class of compounds called terpenoids, which act as chemical signals and can serve as antioxidants. But in the atmosphere, such volatile organic compounds (VOCs) react with other pollutants to produce harmful ozone and particulate pollution called PM2.5.

In places where human sources of air pollution have declined thanks to cleaner vehicles and power generation, emissions from plants have come to play a larger role. But how large is unknown.

Pfannerstill and her colleagues measured VOC emissions in Los Angeles by flying a plane above the city over several days in June 2021. They found terpenoids dominated VOC emissions in many parts of the city. This was especially true in places with the most vegetation, and on days with the hottest temperatures. When temperatures breached 30°C (86°F), terpenoids dominated emissions even downtown, where there are fewer plants and more people (*Science*, doi.org/gtz75n).

Exactly why plants would emit more terpenoids under hotter temperatures is unclear, but it could be a response to heat or water stress, says Pfannerstill.

"Having this direct observation is crucial to building the right models to predict what's going to happen with air pollution tomorrow or years from now," says Matthew Coggon at the US National Oceanic and Atmospheric Administration. ▮

Neuroscience

AI reads brain activity to tell which bit of a movie you are watching

Moheb Costandi

COLLECTION CHRISTOPHEL/ALAMY

Study participants viewed the film *(500) Days of Summer*

MOVIE characters and locations can be deciphered by monitoring the activity of people's neurons while they watch a film, a discovery that could help us understand how the brain stores memories as they are being made.

A deep brain structure called the hippocampus, which is critical for memory, contains neurons that encode the identity of objects, such as tools or buildings. The cells involved then respond to stimuli depicting those objects. But a lot of our knowledge about this comes from studying people while they view isolated images, rather than responding to changing scenes.

To learn more, Franziska Gerken at the Technical University of Munich in Germany and her colleagues turned to 29 people with epilepsy who had electrodes implanted into their brains to monitor for seizures before they underwent surgery for their condition.

The researchers used this opportunity to record the activity of about 2300 neurons in and around each individual's hippocampus while they watched the film *(500) Days of Summer*.

Gerken and her colleagues then used an artificial intelligence model to analyse how these neural responses differed according to specific features of the film, such as characters and locations, and visual categories, like scene transitions.

~2300

hippocampus neurons were scanned as people watched a film

When the participants rewatched the film, the researchers could tell which content people were viewing by looking at the neuronal responses.

The neurons in all the regions in and around the hippocampus responded to the film's features and visual categories, but activity in some regions reflected these more than others. For example, the activity of visually responsive neurons in a region known as the parahippocampal gyrus was linked to scene transitions and locations, while the activity of cells in an adjacent region called the amygdala became activated with the presence of the film's main characters.

Further analysis revealed that, although several thousand cells were activated at different times in response to seeing Summer, the female protagonist, there was no consistent pattern of memory activity linked to her presence on screen. Each time she appeared, a different subset of about 500 neurons became active (bioRxiv, doi.org/m483).

This suggests that large numbers of neurons are activated when a movie character appears, depending on the context, the researchers say in their paper. But when it comes to remembering the character's presence, this information is stored in smaller, changing subsets of neurons, rather than the entire neuronal population.

Rodrigo Quian Quiroga at the University of Leicester in the UK says the results are "very solid" and "a good step forwards to understanding how the memory system functions in real-life situations".

"Neuroscience is full of experiments that are far from real-life memory functioning, so it's valuable to analyse single neuron responses to different movie characters and scenes to disentangle the contribution of different neuron populations to encoding and storing real memories," he says. ▮

Physics

Quantum 'super behaviour' could create energy seemingly from nothing

Karmela Padavic-Callaghan

IN QUANTUM mechanics, the whole can be much greater than the sum of its parts, according to new calculations. They suggest that several low-energy quantum states could be combined into a state with regions that are dozens of times more energetic than any of the constituent components.

One of the more shocking revelations of quantum mechanics is that every object can be viewed as a wave if the circumstances are just right – and the mathematics of what it means to be a wave hides many oddities. Andrew Jordan at Chapman University in California and his colleagues have uncovered a new way to leverage some of those oddities to make quantum states that should have very little energy but actually have a lot.

Their idea builds on the work of Yakir Aharonov, also at Chapman University, who co-authored the new study. In the 1990s, he and his colleagues discovered a phenomenon called "superoscillations". Any wave, from a vibrating guitar string to a wave of light, can be decomposed into several constituent sinusoidal waves, each of which wiggles with some frequency. Aharonov and his colleagues found that if they zoomed in on only one small

"Low-energy quantum states could be combined into a state containing more energetic regions"

region of the main wave, on rare occasions the sum of its constituent waves would add up to wiggle much faster than the main wave's fastest part – forming a superoscillation.

This may not seem surprising, but Jordan says it can have unexpected consequences. For instance, it means that you should be able to take a wave of red light, which has a relatively low frequency, and find a region of it that vibrates at a higher frequency, making it look blue instead – a phenomenon that was observed in experiments. Now, Jordan has expanded the idea to other quantum "super behaviours" by taking advantage of the wave nature of quantum objects.

In the new study, he and his colleagues mathematically proved that in the same way the components of a simple wave can add up to one unexpectedly fast-wiggling region, several quantum states with near-zero energies can combine into a state that has one very energetic region. The research will be published in *Physical Review A*. Jordan says the new paper provides a general recipe for how to apply the idea to your chosen quantum property.

This "superenergy" phenomenon could be tested experimentally and may find uses in light-based experiments and in developing new forms of light-based imaging devices. The caveat, however, is that it would crop up fairly rarely and so you would have to repeat an experiment many times to observe it.

Michael Berry at the University of Bristol, UK, who was involved in early superoscillation studies, says the calculations all come down to "orthodox quantum mechanics, unconventionally applied" to make predictions about quantum properties that are beyond the ranges of those conventionally thought possible. He says there are many related unusual quantum phenomena, including the way a series of waves travelling forwards can be combined into a wave that in some regions travels backwards.

Jordan is collaborating with experimental physicists to attempt to demonstrate more examples of superoscillations in the lab. ▮

Palaeontology

Meet Lokiceratops, the frilliest of dinosaurs

A NEWLY discovered relative of *Triceratops* had a unique array of head ornaments, including the largest frill horns ever seen on a horned dinosaur.

Its fossil remains were found in 2019 near the US-Canada border in Montana. They were purchased by the Museum of Evolution in Denmark, where they are currently on display.

It is thought that the creature, *Lokiceratops rangiformis*, lived around 78 million years ago and would have been about 6.7 metres long, weighing some 5 tonnes.

It had two long horns at the front of its head as well as three main horns on the frill, which is the bony plate extending above its head. The largest frill horns, positioned on each side, were flat, broad and curving in a scimitar-like shape.

They were probably used for display, not defence, and measured more than 60 centimetres along their outer curve, says Joseph Sertich at Colorado State University, who studied the dinosaur along with his colleagues. "By absolute volume and length, *Lokiceratops* had the largest frill horns ever seen," says Sertich.

When it lived – about 12 million years before its most famous Ceratopsid relative, *Triceratops* – its home in what is now the western part of North America was an island continent named Laramidia.

FABRIZIO LAVEZZI/EVOLUTIONSMUSEET/KNUTHENBORG

A reconstruction of what *Lokiceratops* would have looked like

Team member Mark Loewen at the University of Utah named the fossil after the Norse god Loki because its home is now Denmark. The species name, *rangiformis*, refers to the resemblance between the dinosaur's asymmetric middle-frill horns and the asymmetric front tines, or branches, of reindeer antlers (*PeerJ*, doi.org/m449). "Many modern deer have asymmetrical antlers," says Loewen. "We also know that asymmetry is not uncommon in horned dinosaurs, but it is striking in *Lokiceratops*."

Erich Fitzgerald at Museums Victoria in Melbourne, Australia, says the discovery reveals the extraordinary diversity of the Ceratopsid dinosaurs that evolved in the Late Cretaceous epoch of western North America. ▮

James Woodford

Environment

The dark side to brightening clouds

Climate models suggest that a possible scheme to cool the western US by geoengineering clouds could work, but may have severe consequences in Europe, finds **James Woodford**

A CLOUD-modifying technique could help cool the western US, but it would eventually lose its effectiveness and, by 2050, could end up driving heatwaves around the planet towards Europe, according to a modelling study.

There is growing interest in alleviating some impacts of global warming by using geoengineering techniques. These include marine cloud brightening (MCB), which aims to reflect more sunlight away from Earth's surface by seeding the lower atmosphere with sea salt particles to form brighter marine stratocumulus clouds.

Small MCB experiments have already taken place in Australia on the Great Barrier Reef and in San Francisco Bay, California. Proponents hope this approach could be used to reduce the intensity of extreme heatwaves in particular regions as the climate continues to get hotter.

Katharine Ricke at the University of California, San Diego (UCSD), and her colleagues modelled the impact that a possible MCB programme to cool the western US might have under present climate conditions and projections for 2050.

The team modelled the impact of MCB in two locations in the northern Pacific Ocean: one in temperate latitudes and another in subtropical waters. The modelling applied MCB for nine months out of every year for 30 years, essentially altering the long-term climate.

The researchers found that under present-day climate conditions, MCB reduces the relative risk of dangerous summer heat exposure in parts of the western US by as much as 55 per cent. However, it dramatically reduces rainfall in the western US and in other parts of the world, such as the Sahel of Africa.

STOCKTREK/ALAMY

IAN C. BATES/THE NYT/REDUX/EYEVINE

Brightening clouds over the Pacific Ocean (above) using tools like a ship-based spraying machine (left) could help cool the western US

They also modelled the impact MCB would have in 2050, in a predicted scenario where global warming reaches 2°C above pre-industrial temperatures. Under these conditions, the same MCB programme was ineffective and instead dramatically warmed almost the entirety of Europe, except the Iberian peninsula. Ricke says the modelled temperature increase was especially large in Scandinavia, central Europe and eastern Europe.

These far-reaching impacts were caused by changes to large-scale atmospheric currents leading to unexpected consequences (*Nature Climate Change*, doi.org/m45d).

Team member Jessica Wan at UCSD says a big takeaway is that the impacts of regional MCB aren't always intuitive: "Our results provide an interesting case study illustrating the unexpected complexities in the climate system you can uncover through regional geoengineering because of the highly concentrated perturbation to a small part of the planet."

The MCB experiments that have taken place so far in Australia and California haven't been of a sufficiently large scale to cause detectable climate effects, but they suggest that regional geoengineering could be closer to reality than previously thought, says Wan. "We need more regional geoengineering modelling studies like this work to characterise these unintended side effects before they have a chance to play out in the real world."

Ricke says another issue is that if countries start to rely on these methods while they are still effective, it may discourage action to reduce carbon emissions. Then, when the geoengineering stops working, the world would be locked into an even more dangerous trajectory, she says.

"Lock-in is a major concern people have about geoengineering approaches in general because there will be opportunity costs associated with pursuing these approaches," says Ricke. "In a world like the one we simulate, what other risk management approaches would we have invested in developing if we hadn't pursued MCB?"

"It's a huge poke to the global climate system, so of course there will be consequences"

Unrealistic extremes

Daniel Harrison at Southern Cross University in Australia is the project lead of the research looking into whether MCB could be used in the future as a tool to mitigate heatwaves in the Great Barrier Reef region. He says the scenarios modelled by the new paper's authors are "completely unrealistic and extreme". "It's a huge poke to the global climate system, so of course there will be consequences," he says.

The project Harrison is researching would involve MCB over much shorter time periods and in a fraction of the area modelled by Ricke's team, he says.

John Moore at the University of Lapland in Finland says there is an urgent need for more research on solar geoengineering to explore the possible outcomes more thoroughly, including the impact on low-income countries and Indigenous peoples in the Arctic. ▮

Analysis Health

Should people with obesity be paid to lose weight?

Studies suggest that financial incentives lead to weight loss, but whether the approach is sustainable or cost-effective remains to be seen, finds **Grace Wade**

A GROWING body of evidence suggests that paying people to lose weight could be an effective treatment for obesity. While this seems to imply that the condition boils down to just lifestyle choices – an idea doctors have moved away from in recent years – it probably isn't that simple.

Worldwide, 1 in 8 people have obesity, a figure that has more than doubled among adults and quadrupled among teenagers since 1990. Obesity is linked to a higher risk of heart disease, type 2 diabetes and some types of cancer, making it a top healthcare priority, particularly in high-income countries.

For decades, the solution was pinned on encouraging people to eat less and move more. Yet this rarely leads to lasting and significant reductions in weight. People who participate in weight-loss programmes tend to regain more than 75 per cent of the lost weight within five years, for instance.

Part of the issue is adherence. Consuming fewer calories activates brain cells that cause intense hunger, making it difficult to stick with a weight-loss diet. Potentially adding to the challenge is the contentious idea that people can be addicted to certain foods, such as those high in sugar and fat.

Seeking new treatment options, some researchers have recently investigated whether financial incentives could help people with obesity lose weight, and the results are promising.

For example, a 2022 US study offered 660 people with obesity in socioeconomically disadvantaged neighbourhoods the chance to take part in a one-year weight-loss programme, made up of a personalised nutrition plan. About a third of the participants could also receive up to $750, depending on how much weight they lost. After six months, about 49 per cent of those with the prospect of getting paid had lost 5 per cent of their body weight (*JAMA Internal Medicine*, doi.org/m49p), which is often considered the benchmark for a successful weight-loss intervention. The same was true for only 22 per cent of the participants who were just given the nutrition plan.

A similar UK study published in May involved researchers sending daily text messages with weight-management advice and educational resources to nearly 400 men with obesity, of whom 196 were told they would get £400 ($490) at the end of the one-year trial. The catch? The sum would dwindle if they didn't hit certain weight-loss goals. Weight fell by around 5 per cent, on average, in the financial incentive group, compared with about 3 per cent in the text-only group (*JAMA*, doi.org/m49q).

$330

Average reward given to adolescents paid to lose weight in one study

To see if this strategy also works in adolescents, Amy Gross at the University of Minnesota and her colleagues provided meals designed for weight loss to 126 teenagers with severe obesity for a year. Half of the participants also received $20 gift cards for every 0.5 per cent drop in body weight. The team found that the adolescents' body mass index fell by almost 6 percentage points more in the group getting gift cards (*JAMA Pediatrics*, doi.org/m49r).

One issue with all these studies is that we don't know if the participants maintained their weight loss once the financial incentives stopped. When it comes to the long-term cost-effectiveness of such an approach, only Gross's team attempted to calculate this, discovering that the benefits that came with the gift cards worked out as more cost-effective than those from the meals alone.

The team didn't compare the approach's cost-effectiveness to any other weight-loss interventions. But the participants in the financial incentive group received about $330, on average, in gift cards over the year, while an annual supply of the popular weight-loss medication Wegovy costs roughly $16,000.

It can cost more to include healthier foods in your diet

WESLEY SOARES FERRACINI/GETTY IMAGES

One also has to consider the cost of treating obesity-related conditions. The health service in England and Wales spends 10 per cent of its budget – more than £1.5 million an hour – treating diabetes, with type 2 diabetes making up the vast majority of these cases. It remains to be seen whether financial incentives for weight loss would make a meaningful dent in this expense.

The prospect of money or gift cards probably increases motivation to lose weight, but they could also help people afford the produce that makes up a nutritious diet, as well as other expenses. "It costs money to buy healthy fruits and vegetables," says Pat Hoddinott at the University of Stirling in the UK. "It costs money because your clothes don't fit."

As to whether lifestyle changes alone can treat obesity, Hoddinott doesn't believe it is that simple.

For starters, the weight reductions achieved in these studies pale in comparison with those attained via Wegovy or the drug Zepbound, which decrease weight by about 15 to 20 per cent, on average, in trials.

Obesity is also "extraordinarily complex", says Hoddinott. People may live in "food deserts", areas without affordable, nutritious options, or in places without parks or other spots that are conducive to exercise, says Gross. Our genetics also plays a role in our weight. "We're going to need a lot of tools in the toolkit to treat it," says Gross.

This is why paying people to lose weight probably won't suffice on its own, but it could be combined with other interventions. It may also be a better fit for certain people, like those who have intolerable side effects from weight-loss drugs, says Hoddinott.

"Whatever you do for weight loss, when the intervention stops, people put on weight," she says. ▮

Zoology

Sleeping on the job

Prizewinning photo captures cuckoo bees clinging to grass as they snooze

James Dinneen

THIS dazzling close-up catches two black-thighed cuckoo bees (*Epeolus variegatus*) as they sleep. Lest they fall off their perch, they have anchored themselves with their mandibles to blades of grass. The bees sleep in the open because they have no nests of their own, much like the birds from which they get their name.

They are what is known as kleptoparasites – females sneak into the nest of other bee species and lay their eggs in unsealed egg cells there. When the *E. variegatus* larva hatches, it eats the egg of the host bee and then feeds on the store of pollen that was left in the cell.

The image, taken in the UK by photographer Luke Chambers, is the overall winner of the 2023 Royal Entomological Society Photography Competition, which showcases amateur photography from around the globe that brings the miniature world of insects into focus. ▮

LUKE CHAMBERS

Technology

Driverless cars safer than humans – when it's light

SELF-driving cars are normally safer than human drivers, but struggle more during low-light conditions, according to a study of accidents.

Autonomous vehicles drive in several US cities. For example, Google spin-off Waymo has been gradually expanding robotaxi operations in Los Angeles; San Francisco; Austin, Texas and Phoenix, Arizona.

Shengxuan Ding and Mohamed Abdel-Aty, both at the University of Central Florida, have pulled together data on 2100 accidents in California involving vehicles equipped with some level of automated self-driving or driver assistance technologies.

They also gathered data on more than 35,000 accidents in the state involving unassisted human drivers.

Next, they used a statistical matching method to find pairs of accidents that occurred under similar circumstances, with shared factors such as road conditions, weather, time of day and whether the incident took place at an intersection or on a straight road. They focused this matching analysis on 548 self-driving car crashes reported in California, excluding less automated vehicles that only have driver assistance systems.

"Self-driving cars had a crash risk five times as great as human drivers at dawn and dusk"

The overall results suggest autonomous vehicles "generally demonstrate better safety in most scenarios", says Abdel-Aty. But the analysis also found self-driving cars had a crash risk five times as great as human drivers when operating at dawn and dusk, along with almost double the accident rate of human drivers when making turns (*Nature Communications*, doi.org/m4mw).

Improving the safety of autonomous vehicles at these times could be done by enhancing weather and lighting sensors in the cars, says Ding.

"I think it is an interesting but extremely preliminary step towards measuring autonomous vehicle safety," says Missy Cummings at George Mason University in Virginia, but she says the number of recorded crashes is too low to draw firm conclusions.

Minor fender benders may not get reported to police, so comparisons of autonomous vehicle crashes versus human driver crashes need to account for that, says Eric Teoh at the Insurance Institute for Highway Safety in Virginia. His 2017 study of Google's tests of self-driving cars found just three out of 10 specific crashes made it into police reports. ▮

Jeremy Hsu

Chemistry

Maxwell's demon invoked on the largest scale yet

Alex Wilkins

A PUMP based on a thought experiment involving a "demon" could be used in drug manufacturing.

In 1867, physicist James Clerk Maxwell theorised two boxes of gas separated by a weightless door controlled by a tiny demon. The demon lets faster-moving particles pass through in one direction and slower particles in the other, which makes one box hotter and the other cooler. But this seems to violate the second law of thermodynamics, which says heat must flow from hot to cold unless energy is used to make things go the other way.

Physicists went on to solve this paradox by realising that a demon would have to expend energy to measure the speed of each particle. People later spotted real-world examples of Maxwell's demon working at very small scales.

Now, Jonathan Nitschke at the University of Cambridge and his colleagues have designed a chemical pump inspired by the idea. It can separate molecules over several centimetres, the largest distance so far. Their set-up is a U-shaped tube filled with a light-sensitive chemical called fluoroazobenzene (FAB). The bend is filled with water and pyramid-shaped molecules called coordination cages, which can contain certain molecules and carry them from one side of the bend to the other. These cages are the equivalent of the demon opening or closing the door (*Nature Chemistry*, doi.org/m4md).

When Nitschke and his team shine light on one side of the tube, the FAB changes its configuration to more easily fit in the cage, which transports it to the other side. As a result, FAB accumulates on one side. "We're providing light energy," says Nitschke. "That's what feeds the demon."

The system could help separate chemicals in industries like drug manufacturing, he says. ▮

Archaeology

Easter Island's supposed population collapse probably never happened

James Woodford

THE widespread claim that the ancient people of Easter Island underwent a societal collapse due to overexploitation of natural resources has been thrown into fresh doubt. Instead, a small and stable population lived sustainably for centuries before the arrival of Europeans, a new analysis of historical farming practices suggests.

Famous for its towering stone statues, Easter Island – also known as Rapa Nui – lies in the Pacific Ocean and is thought to have been inhabited by Polynesians since around AD 1200. At that time, its 164 square kilometres were covered in palm forests, but these were destroyed quickly, probably by a combination of overharvesting and rats eating fruit and blooms.

According to a popular narrative, the unsustainable use of resources led to runaway population growth and a subsequent collapse before Europeans arrived in 1722.

The islanders mainly supported themselves through rock gardening, a form of agriculture that has been widely practised in places where soils are poor or the climate harsh. Stones are scattered around fields to create microhabitats and windbreaks, preserve moisture and supply minerals.

CARL LIPO

Researcher Robert DiNapoli inspects a rock garden on Easter Island

Previous studies have suggested that as much as 21 square kilometres of Rapa Nui was covered in rock gardens, supporting a population of up to 16,000 people.

4000

people could have been fed by agriculture on Easter Island

To find out more, Carl Lipo at Binghamton University in New York and his colleagues used satellite imagery combined with machine-learning models trained with ground surveys to generate an island-wide estimate of rock gardening sites.

This revealed that the maximum area of the stone gardens was only 0.76 square kilometres. The researchers estimate that such a system would have been able to support about 4000 people – roughly the population estimated when Europeans arrived (*Science Advances*, doi.org/m422). In other words, the team argues, the population remained remarkably stable.

Lipo says that those who continue to use Rapa Nui as a case study of degradation and collapse need to look at the empirical evidence. "The results we produce continue to support our hypothesis that the island never... [had] a massive population that overconsumed its resources," he says. "Overall, we do not see evidence in the archaeological record of a population collapse before European arrival."

Instead, there is growing weight behind the suggestion that islanders transformed their environment in ways that allowed them to live sustainably for generations, says Lipo. "Small populations and low-density, dispersed settlement patterns enabled the communities to reliably produce sufficient food for more than 500 years until the arrival of Europeans."

The Rapa Nui people are often portrayed as a culture that collapsed because of ecological overexploitation, says Dale F. Simpson at the University of Illinois. "The discussion would be better served if it recognised the Rapa Nui as a Polynesian island culture of adaptation and survival that has thrived for almost a millennium." ▮

SHUTTERSTOCK/VETY MARIA

The residents of Rapa Nui created iconic statues called moai

Zoology

Sick chimps seek medicinal plants

Chimpanzees with wounds or infections eat plants with antibacterial or anti-inflammatory properties

Paris Jaggers

SEVERAL plants eaten by chimpanzees when they are ill or wounded have been found to have medicinal effects, providing some of the strongest evidence yet that our close relatives practise self-medication.

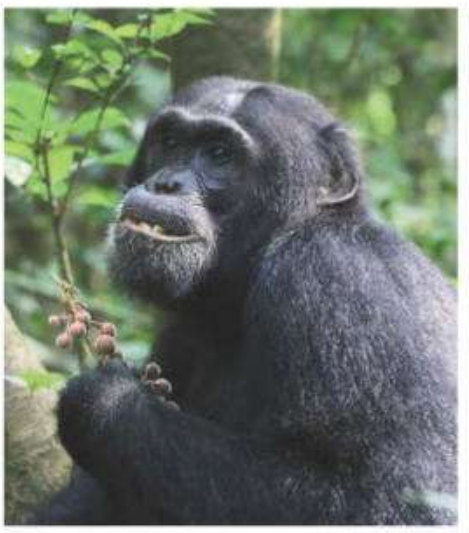
Reports of chimpanzees self-medicating with plants have been around for decades, but it is difficult to establish when wild animals are ill and what effect their diet has.

Now, Elodie Freymann at the University of Oxford and her colleagues have followed wild chimps through Budongo Forest in Uganda, recording when they were ill and what they ate.

The researchers identified chimps with obvious wounds or with gut infections by analysing their faeces for signs of intestinal worms, as well as checking urine samples for raised levels of immune cells.

Analysis of 53 extracts of plants consumed by the ill or injured chimps showed that 88 per cent were active against bacteria that are pathogenic in humans, including antibiotic-resistant strains like MRSA. Extracts from every sampled species had anti-inflammatory effects (*PLoS One*, doi.org/m4k7).

A chimpanzee eating forest sandpaper figs (*Ficus exasperata*), which contain anti-inflammatory compounds



ELODIE FREYMANN

Sick chimps often left the safety of their group to find and eat specific plants, and picked out species only rarely eaten in the area. The infrequency of these events is what makes self-medication so hard to observe, but also provides one of the strongest pieces of evidence that it is a targeted response to illness.

Chimpanzees are usually reluctant to try unfamiliar foods that might be dangerous, says Freymann. Choosing to eat unusual plants therefore suggests they have particular reasons for doing so. "If you're sick, you're not going around stuffing things that could make you sicker in your mouth," she says.

"It's a very impressive project," says Kirsty Graham at the University of St Andrews, UK. But this might not capture everything that is going on, because chimps' diets are still very diverse, she says. If the animals learn which plants to eat from others, over generations the community might overcome this reticence towards new foods.

Directly comparing the diets of sick and healthy chimps at the same time might clarify whether these are active choices, she suggests.

"If you're sick, you're not going around stuffing things that could make you sicker in your mouth"

Team member Fabien Schultz at the Brandenburg University of Applied Sciences in Germany hopes that identifying the active compounds in the plant extracts might lead to promising candidates for human medicines. "What if human lives can be saved by following the ways of our animal relatives?" he says. ▮

Health

Walking helps keep people free of lower back pain for longer

IF YOU experience recurring bouts of lower back pain, you might be able to stave off debilitating episodes for longer by going for regular walks.

More than 600 million people globally get pain in this part of the back, which often recurs. Yet there is little research into its prevention, says Tash Pocovi at Macquarie University in Sydney, Australia.

Wanting to find an affordable and accessible way for people to avoid this type of pain, Pocovi and her colleagues designed "WalkBack", the first controlled trial of its kind. They selected 701 people, aged between 20 and 82 years old, who lived in Australia and had experienced an episode of lower back pain without a specific diagnosis, such as a fracture or infection, within the previous six months that then resolved.

On average, they had each had 33 episodes of lower back pain, which interfered with their daily activities and lasted at least 24 hours. None of the participants regularly chose to go for recreational walks or engaged in any exercise programme for pain management.

The researchers asked 351 of them to develop an individualised walking programme with the help of a physical therapist, aiming for a gradual build-up to 30 minutes of walking, five days a week, within six months. The programme varied for each individual to help them stick to it, says Pocovi. By 12 weeks, the participants were walking an average of 130 minutes per week.

They were also told about the latest scientific knowledge regarding lower back pain, which was meant to reassure them that it is safe to walk, says Pocovi. "A lot of people become avoidant and fearful of movement when they have a history of back pain," she says.

The other 350 volunteers received no such education or walking programme advice. Pocovi and her colleagues followed all the participants for up to three years. Regardless of the group they were in, they were free to seek any additional treatment for their pain.

On average, people in the treatment group had their first recurrence of activity-limiting lower back pain 208 days after the study began, compared with 112 days in the control group (*The Lancet*, doi.org/m4mf).

Furthermore, half the people in the control group sought other interventions, such as massages and chiropractic treatment, compared with only 36 per cent of those following the walking and education programme. However, those walking were more likely to experience mild complications of exercise, such as sprains. ▮

Christa Lesté-Lasserre

600m+

Number of people worldwide experiencing lower back pain

Environment

Farmland near Chernobyl safe to use

Radiation surveys suggest it is finally safe to grow food on farmland in Ukraine that has been unused since the 1989 meltdown of the Chernobyl nuclear reactor. But will it happen, asks **Michael Le Page**

LARGE areas of farmland around the Chernobyl nuclear reactor that are officially classed as contaminated now appear to be safe to use for growing food. Surveys show radiation levels have fallen below the levels regarded as unsafe according to Ukrainian regulations.

Changing the status of this land could help compensate for farmland lost as a result of the Russian invasion of Ukraine.

"More than 80 per cent of [surveyed] territory can be returned to agricultural production," says Valery Kashparov at the National University of Life and Environmental Science of Ukraine, whose team has been assessing the radioactivity of the land for more than a decade.

Evacuations and bans

In 1986, one of four reactors at the nuclear power plant near Chernobyl – or Chornobyl in Ukrainian – went into meltdown during a test, causing an explosion and fire that released radioactive isotopes of elements including iodine, caesium, strontium and plutonium into the atmosphere. The most highly contaminated land was evacuated and farming was banned across a larger area.

The large quantities of iodine-131 released were the biggest health threat. However, this isotope has a half-life of just eight days, so it declined to negligible levels within years.

Other isotopes, such as caesium-137 and strontium-90, have a half-life of around 30 years, so while levels have more than halved, they remain present in the soil around the region.

In the main exclusion zone closest to the nuclear plant, which may become a nature reserve, levels are still high in many places. But further out, on land that is still officially classified as radioactively contaminated, they have fallen below the threshold regarded as dangerous.

The most recent survey was carried out in 2023 by Volodymyr Illienko, also at the National University of Life and Environmental Science. He and his colleagues measured radioactivity levels on 2600 hectares around the settlements of Narodychi and Vyazivka. "We didn't find a higher level than permissible," Illienko told *New Scientist*.

Altogether, about 130,000 hectares of farmland outside the exclusion zone is classified as radioactively contaminated but could be brought back into use if wider surveys find they are safe, says Illienko.

In places, some fields or parts of fields do exceed the limits, says Jim Smith at the University of Portsmouth, UK. However, in yet-to-be-published work done in conjunction with Kashparov, he has shown that little of this radiation is transferred to crops.

If farming is officially allowed to resume, this should be confirmed by testing food directly as well, says Smith. "And we've also done some modelling of what doses to farm workers would be, and they're very, very low."

"Government bodies are afraid of negative public opinion. But war requires optimisation of funds"

There shouldn't be any issue with exporting this food, given that the Ukrainian limits for radioactive contamination in food are much stricter than those in the UK or European Union. That is because Ukraine's limits are designed to ensure that people don't get a dangerous cumulative dose over time.

However, the situation on the ground is complex. Some people have already moved into these regions and begun farming them again, leading to legal wrangles about both the sale of the produce and who owns the land.

Some of the products grown in the "contaminated" regions are already exported, in the form of spirits branded as Atomik in the UK, with profits going back to the local communities. Tests confirm that there is no radioactivity, says Smith, who is involved in this social enterprise.

The political situation is also complex. There is opposition to the status of the land being officially changed from contaminated to uncontaminated, because this would end compensation payments.

"Radiological agricultural issues are the easiest part of this problem," says Oleg Nasvit at the National Institute for Strategic Studies in Kyiv. "The main part is [the] privileges and payments of the people living on 'contaminated' territories, which are not really contaminated any more, but the government is unable to announce these territories as uncontaminated because of the threat of massive protests."

"Government bodies are afraid of negative public opinion," says Kashparov. "[But] war requires optimisation of the use of public funds."

Smith says that the risks posed by radioactive contamination from the disaster need to be seen in context. We are all continuously exposed to low levels of natural radiation, including from the food we eat.

And while the disaster may have led to about 15,000 deaths from cancers across Europe, including future deaths, this is relatively small in comparison with, say, estimates of deaths due to air pollution, he says. ▮

SERGEY DOLZHENKO/EPA-EFE/SHUTTERSTOCK

Radiation measurements in the Chernobyl exclusion zone, Ukraine

Materials science

Glassy gel is as hard as plastic but also stretchy

Karmela Padavic-Callaghan

A NEW, gel-like material is soft enough to stretch to almost seven times its original length while still being strong and clear.

Michael Dickey at North Carolina State University says the "glassy gels" that he and his colleagues devised are more than 50 per cent liquid, but as strong as the plastics used for water bottles.

Each glassy gel consists of long molecules called polymers mixed with an ionic liquid, a fluid that is essentially a salt in liquid form. The gel is a transparent solid that can withstand up to 400 times atmospheric pressure, but also stretch easily up to 670 per cent (*Nature*, doi.org/gtz43b). Dickey says this could make it suitable for building soft, robotic grippers or 3D printing deformable materials.

If you damage this new material, it can be repaired by applying heat

M WANG/NC STATE UNIVERSITY

He and his colleagues found that the strength and stretch depended on the ratio of polymers and liquid salts used.

"Just by changing the ratio of two ingredients, you can go from something very stretchy like a rubber band, to something almost as hard as glass," says Dickey.

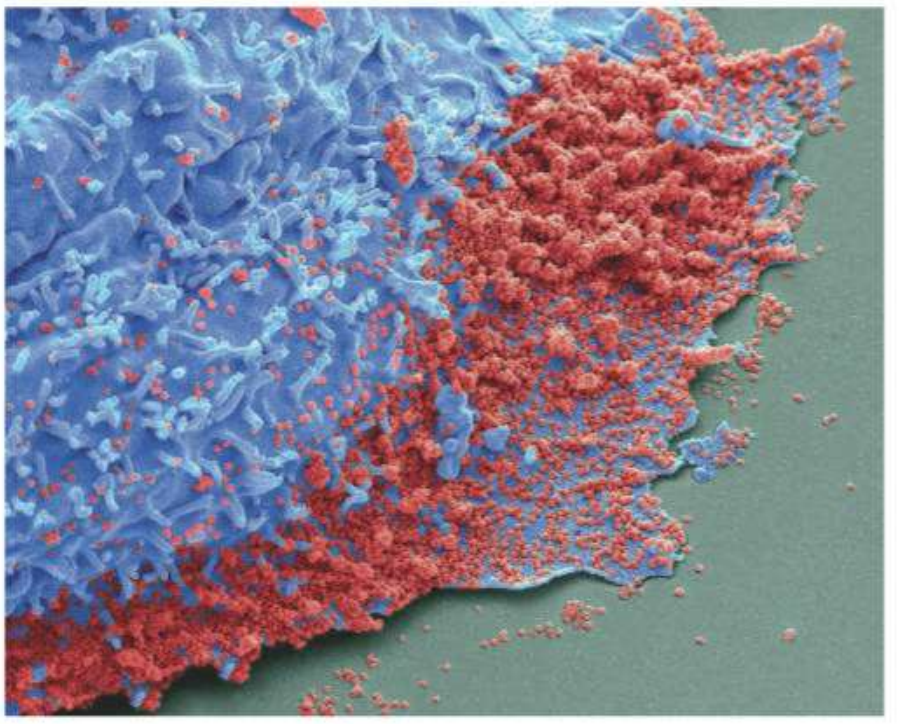
This is because the materials get their stretchiness from the ionic liquid settling into spaces between the stiffer polymer molecules and pushing them apart, while their strength comes from the electrostatic attraction between the liquid's charged particles and the polymers, which prevents them from fully breaking apart.

If damaged, the glassy gels can be repaired by applying heat, which makes molecules on the broken edges reconnect. ▮

Covid-19

We finally know why some people seem immune to the coronavirus

Sonali Roy



STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY

SARS-CoV-2 viruses (the red dots) budding from a human gut epithelial cell

DELIBERATELY exposing people to the coronavirus behind covid-19 in a so-called challenge study has revealed why some people seem to be immune to catching the infection.

As part of the first such work using the SARS-CoV-2 pathogen, which was carried out in 2021, a group of international researchers looked at outcomes for 16 people. All had no known health conditions and hadn't tested positive for the virus or been vaccinated against it.

To try to deliberately infect them, Sarah Teichmann at Cambridge Stem Cell Institute in the UK and her colleagues sprayed the original variant of SARS-CoV-2 up their noses. The researchers took nasal and blood samples before this and then six to seven times over the 28 days after. SARS-CoV-2 tests were done twice a day.

Following exposure to the virus, the participants fell into three groups, says Teichmann. In one, six people tested positive in both of their daily tests for more than two days, while also having symptoms. In another, three participants tested positive in one of their twice-a-day-tests, but not the other, for no more than two days, without symptoms. In the final group, seven people consistently tested negative for the coronavirus.

In total, the researchers also looked at more than 600,000 blood and nasal cells taken from all the individuals.

Teichmann and her colleagues found that in the second and third groups, the participants produced interferon – a substance that helps the immune system fight infections – in their blood before it was produced in their nasopharynx, the upper part of the nose behind the throat. This is the place where the nasal samples were taken from.

16

Number of people deliberately exposed to SARS-CoV-2 virus

7

This many of them consistently tested negative for the virus

The interferon response, when it did occur in the nasopharynx, was actually higher in the noses of those in the second group than the third, says Teichmann.

These two groups also didn't have active infections within their T-cells and macrophages, which are both types of immune cell, says team member Marko Nikolic at University College London.

The results also suggest that high levels of activity of an immune system gene called *HLA-DQA2* before SARS-CoV-2 exposure helped prevent a sustained infection (*Nature*, doi.org/m4jg).

Nikolic hopes the findings will improve understanding around the cell responses associated with covid-19 protection, which could assist with vaccine and treatment development.

"This study serves as a unique resource of previously uninfected SARS-CoV-2 participants due to its carefully controlled design and real understanding of 'time zero' for when the infection took place in order to measure the immune responses that follow," says José Ordovas-Montanes at the Harvard Stem Cell Institute in Massachusetts.

However, most people have now been exposed to "a veritable mosaic of SARS-CoV-2 variants", rather than just the ancestral variant used in this study. This therefore means that the results may not reflect cell responses outside a trial setting, he says. ▮

Space

Dwarf planet Pluto and Neptune's moon Triton might be siblings

Jonathan O'Callaghan

NEPTUNE'S largest moon, Triton, and the dwarf planet Pluto may have shared a common origin before being separated, an analysis of their composition suggests.

Triton and Pluto are both icy bodies smaller than Earth's moon, have similar densities and appear to have hosted subsurface oceans at some point in the past.

Unusually, Triton, which is about 50 per cent more massive than Pluto, orbits in the opposite direction to its planet's rotation – the only large moon to do so in the solar system. This has led to suggestions it may have originated in the Kuiper belt, a region of icy objects like Pluto that exist beyond Neptune, because moons that formed with Neptune should match its spin.

Kathleen Mandt at NASA's Goddard Space Flight Center in Maryland and her colleagues have now gone further by suggesting that Triton and Pluto formed close to each other before the solar system settled down. "They probably formed in the same region, which wouldn't be where the Kuiper belt is now – it would have been either closer or further away," says Mandt.

JPL/NASA/SOUTHWEST RESEARCH INSTITUTE

Triton, far left, and Pluto (not to scale) have similar amounts of certain key elements

Studying prior data on the two bodies, the team found that both have a large amount of nitrogen and trace amounts of methane and carbon monoxide, which could have accumulated in the outer regions of the young nebula surrounding our sun 4.5 billion years ago (arXiv, doi.org/m4jc).

"For some reason, Triton was then ejected from this region and ensnared by Neptune"

This suggests they both formed in cold outer regions of the early solar system, which were rich in nitrogen. But they also have low amounts of water, similar to some known icy comets such as comet C/2016 R2 (PanSTARRS) that may have come from a similar location.

"They had to have formed beyond the water-ice line," says Mandt, referring to the distance from the sun where water would freeze into ice or snow, which is where Jupiter is now. She says the two bodies would have formed within 1 to 5 astronomical units (AU), or sun-Earth distances, of each other based on their shared compositions and dynamical modelling of the solar system, and no more than 30 AU from the sun.

For some reason, Triton was then ejected from this region and ensnared by Neptune. One possibility is that the giant planets moved closer to the sun early in the first 100 million years or so of the solar system, which may have disrupted the orbits of some bodies like Triton.

Pinning down the origins of Triton and Pluto could give us new insights into how our solar system came to be, says Paul Schenk at the Lunar and Planetary Institute in Texas. "It's an indication there was more than one Pluto," he says. "It's probable there were other bodies of similar size and composition that were lost." ▮

Zoology

Bloodsucking leech jumps by coiling its body like a cobra

FOR the first time, scientists have documented leeches leaping from leaves, settling a centuries-long dispute over the bloodsuckers' ability to jump.

The question of whether leeches can jump has been debated since rumours of the behaviour emerged in the late 1800s. There have been occasional sightings since, but now there is conclusive evidence.

When doing fieldwork in Madagascar in 2017, Mai Fahmy at Fordham University in New York encountered a *Chtonobdella* leech (*Chtonobdella fallax*) – a terrestrial species that lives solely on the island.

"I squatted next to it on the ground, and I took out my phone and started recording," says Fahmy. "At the time, I didn't realise what I had captured." When she showed the video to her colleagues back in New York, Fahmy says they all had the same reaction: did that leech just jump? Six years later, Fahmy returned to Madagascar to find out and recorded the behaviour again.

The leeches prepare by anchoring their rear sucker to a surface like a leaf and coiling the rest of their body backwards. Then, in one rapid motion, they launch their body forwards, much like a striking cobra, unsticking their rear sucker and becoming airborne (*Biotropica*, doi.org/m4jp).

MAI FAHMY

The *Chtonobdella* leech can coil back its body and then launch it forwards

The sudden burst of movement may be a tactic to land on or near unsuspecting prey. The leap is a bit awkward, but "this is very clearly an active form of propulsion", says team member Michael Tessler at Medgar Evers College in New York.

Finding this ability in two different individuals and locations "suggests that this behaviour is more common than we might have anticipated", says Tessler. He suspects this isn't the world's only jumping leech species. ▮

Corryn Wetzel

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Comment

What a nerve!

Influencers are obsessed with the health benefits of stimulating the vagus nerve. But we should be wary of their claims, says **Kevin Tracey**

IT WAS 25 years ago, but I clearly remember the lunch meeting when I drew a simple sketch of the vagus nerve on a napkin, showing the signals it carried from the brain to the body to turn off inflammation.

Sitting in a steakhouse with Ralph Nappi, the former chair of the board of the Feinstein Institutes for Medical Research, I explained my lab's discovery that stimulating electrical signals in the vagus nerve could prevent inflammation. My ballpoint stick figure predicted a scientific journey that is now likely to disrupt broad segments of the healthcare industry, and benefit millions of people.

So it is with fascination – and some bemusement – that I observed this decades-old discovery become a burgeoning new social media trend. Scrolling through your favourite apps, you will find influencers suggesting you can stimulate your vagus nerve by rolling your eyes, massaging your neck, chanting and humming or jumping in cold water. On TikTok alone, #vagusnerve has garnered more than 185 million views.

But a very real distinction should be made between what influencers call vagus nerve "stimulation" and the vagus nerve-stimulating devices approved by the US Food and Drug Administration to treat strokes, depression, opioid withdrawal and epilepsy. Hopefully, inflammation will one day be added to this list.

SIMONE ROTELLA

There are two vagus nerves on each side of your neck, made up of over 100,000 fibres like an undersea cable. These transmit the "inflammatory reflex", which connects the brain to your immune system. Research from my lab and others shows that small, pacemaker-like devices can turn on the inflammatory reflex to control the release of inflammatory proteins called cytokines.

Inflammation is the major problem in autoimmune conditions like Crohn's disease and rheumatoid arthritis. And since it also contributes to more than 50 per cent of deaths worldwide, including ones from heart disease, stroke, cancer, diabetes, obesity and Alzheimer's disease, the implications for potentially treating many other conditions cannot be overstated.

But before accepting free social media advice on this topic, I recommend checking the evidence. Scientists are just starting to map and understand what the 100,000 vagus nerve fibres do. So when you are advised to "stimulate your vagus nerve" by taking a deep breath or ice bath, you should ask: "Which of my vagus nerves?" The answer is that no one knows.

In the lab, we can use specific, sophisticated molecular techniques such as light stimulation to stimulate selected vagus nerve fibres. We can force a communication flow from the brain to slow down the heart or to suppress the release of cytokines causing dangerous, painful inflammation. But immersing yourself in an ice bath isn't selective. It activates countless vagus nerve fibres, and it also activates other nerves that control your fight or flight responses. Cold immersion might be better called "nervous system stimulation".

So, as much as we have learned about the vagus nerve, we still have a long way to go. That is what scientists around the world are doing. They are working to better understand the basic functions of the vagus nerve and performing clinical trials to study the efficacy of vagus nerve stimulation as a way to treat a variety of conditions in this burgeoning field.

In the meantime, hum a tune or even jump in a cold shower if your doctor says it is OK, but as you cool down, think about the decades of scientific work that started you on the journey to "stimulate" this powerful nerve. Then recall that there is still more work – much more, in fact – to be done. ▮

Kevin Tracey is the chief executive of the Feinstein Institutes for Medical Research, New York

Field notes from space-time

The arrow of time

We don't yet know why time always moves forwards, but some physicists are looking for answers that invoke the evolution of entropy, says **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an associate professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her most recent book is *The Disordered Cosmos: A journey into dark matter, spacetime, and dreams deferred*

Chanda's week

What I'm reading
I'm working my way through Night Flyer: Harriet Tubman and the faith dreams of a free people *by Tiya Miles.*

What I'm watching
I quite enjoyed the 1960s French classic film La Piscine.

What I'm working on
I'm writing the final 20,000 words of the first draft of my next book, The Edge of Space-Time.

This column appears monthly. Up next week: Graham Lawton

TIME is a huge problem. Of course, there is our social and biological sentiment about it: we all want more of it and/or are worried about its passage. As I come up against the deadline for turning in my next book, I'm feeling that strongly. But there is also a deeper physical issue, which is that we don't know why it always moves forwards. This is true even in the context of relativity, where space and time are unified.

You would think that might give the phenomenon some flexibility. In fact, a few columns ago, I pointed out that soap operas are a great way to think about how time works in special and general relativity, since time dilation seems to be central to that style of storytelling. By this, I mean that time flows faster for some plot lines than others in the shows I watch (*Emmerdale* and *Coronation Street*). This is akin to the way time passes differently in special relativity for observers who are moving relative to one another.

It is also similar to the way that the presence of a gravitational field affects the flow of time. Time passes slower close to a massive object and faster when there is less gravity. So, for example, someone at sea level will measure a different time flow rate than a Sherpa at the top of Mount Everest.

But while time is relative, it still flows in one direction for every observer. Sure, people might disagree about how much time has passed during an event, but they will still agree that as time passed, it always moved forwards.

It isn't clear why this should be so – why space-time emerged with an arrow of time. It is also the case that my *Emmerdale* model ignores the existence of quantum mechanics, which has various ways to throw a wrench into our understanding of how time works.

One of the features of quantum mechanics is that it is less predictive than Newtonian physics. While this doesn't affect the flow of time per se, it does complicate how we might think about our expectations that we can predict what will happen next. Quantum predictions are less certain.

Another prediction of quantum mechanics is the phenomenon of entanglement. Imagine two particles that are close enough to each other that they are capable of interacting with each other. Then the particles part ways – perhaps they are two relativistic particles, moving almost at the speed of light. In a classical physics picture, we expect that the particles are no longer connected when they have a sufficiently large spatial distance between them. Not so in quantum mechanics. There they remain entangled, meaning that if we change one correlated property in one of the particles, the other will also change accordingly.

"People might disagree about how much time has passed, but they will agree that it always moved forwards"

This should trouble you. If you remember relativity, you know that the speed of light is finite. That means information isn't supposed to travel between distant locations instantaneously. It should take time for it to get from point A to point B, with the speed of light being the fastest that it can move.

Yet in the quantum entanglement scenario, information seems to flow instantaneously between particles. In other words, the particles have a concept of simultaneity, but only with each other and only after they have been set up together to start in a specific way.

It does seem that quantum mechanics can give us a hint about the arrow of time. One of the laws that can be shown to emerge from quantum calculations is the second law of thermodynamics. This says that the amount of entropy – which is roughly a measure of disorder – in a system tends to grow.

This idea was first found in experiments that pre-date the advent of quantum mechanics, but it was later shown that it could be proven from quantum theoretical principles. Given the correlation between the tendency of entropy to increase and the tendency of time to increase, physicists who think about the arrow of time have tried to explain it by looking for answers that invoke the evolution of entropy.

There are scientists who see it otherwise. In his book *The Janus Point: A new theory of time*, Julian Barbour points out that if we look at cosmological scales, the universe doesn't tend towards disorder, but rather towards complexity. He argues that to understand the arrow of time, we have to think about what drives the evolution of complexity. He even claims it might explain how entanglement works, but he doesn't explain how to make this consistent with relativity.

Of course, none of this thinking changes the challenges we face with time in our everyday lives – at least not yet. But next time you are feeling stressed or frustrated about time, just remember that no one understands it and that this mystery can inspire some of our most creative thinking. ▮

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Rothamsted research: Digging deep to reduce acrylamide

Acrylamide is a potential carcinogen that is formed during high-heat cooking. Rothamsted Research, a pioneer in agricultural science, is digging deep to unearth solutions to reduce the amount of acrylamide that ends up in our diet.

Acrylamide does not occur naturally in foods. It is formed when asparagine, an amino acid, is heated with sugars, in everyday food processing and kitchen activities such as baking, frying, toasting or roasting. This is known as the Maillard reaction; the chemical process that also causes food to brown and forms flavour and aroma compounds from other amino acids.

This means that to reduce the acrylamide in the final processed food, Rothamsted researchers like Nigel Halford are using leading edge gene-editing techniques to create crop strains with significantly lower asparagine.

"We have two lines of gene edited wheat; one with 30-50% of the free asparagine of the control group, and a second with just 10%" says Halford.

Whilst acrylamide's potential to cause cancer has been proven in animals, it is currently classified as a 'probable carcinogen' in humans. However, the European Commission has set mitigation measures and benchmark levels for the reduction of the presence of acrylamide in food and are looking to introduce statutory maximum levels soon. At the moment it is unclear if the Food Standards Agency will advise the UK government to follow suit.

"The proposed maximum levels we've seen are going to be quite challenging," says Halford. "And of course, if you're above the maximum level, it will be illegal to sell the product. So you will have a very expensive, difficult and embarrassing product recall to go through."

So with the increasing focus on reducing acrylamide in our food, Rothamsted Research is a real leader in removing this probable carcinogen from our diets.

You can find out more by visiting the Future of Food and Agriculture stand at New Scientist Live 2024. For more details go to: live.newscientist.com

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A lonely life

Photographer **Ignacio Evangelista**

THESE solitary structures were once a key pillar of aviation navigation, but, due to their remote locations, today they are little known. Photographer Ignacio Evangelista's starkly beautiful shots shine a light on the beacons, dubbed VORs (very high-frequency omnidirectional range stations), and their role in carving out routes in the sky for aircraft.

Essentially giant antennas, VORs beam out radio signals from secluded spots to allow planes to fix their location and stay on course by flying from VOR to VOR. The signals can be thought of as "breadcrumbs", says Evangelista. The isolation is necessary to avoid interference in broadcasts between VORs.

Stations like the ones pictured here are a dying breed, as they are increasingly being decommissioned in favour of satellite-based GPS. But although GPS may be a more accurate means of navigation, VORs offer a back-up during events like solar storms or GPS interference, without which there could be a great deal of chaos, says Evangelista.

Because their locations are publicly available, anyone can seek out a remaining VOR simply by using GPS – a "curious technological pirouette", as Evangelista puts it. This set him on course to document some of the more photo-worthy stations before they disappear for good.

Clockwise from the far left, the first two stations are in Spain – VOR NVS is on the edge of the village of Navas del Rey, 50 kilometres from Madrid, while VOR CMA is 1.5 km from the village of Calamocha. The last, VOR BRY, is on the edge of French village Bray-sur-Seine.

Gege Li

Sponsored by Roche

Prioritising the global brain health crisis

The social and economic cost of brain disorders is growing rapidly. Driving global policy change through collaboration is key

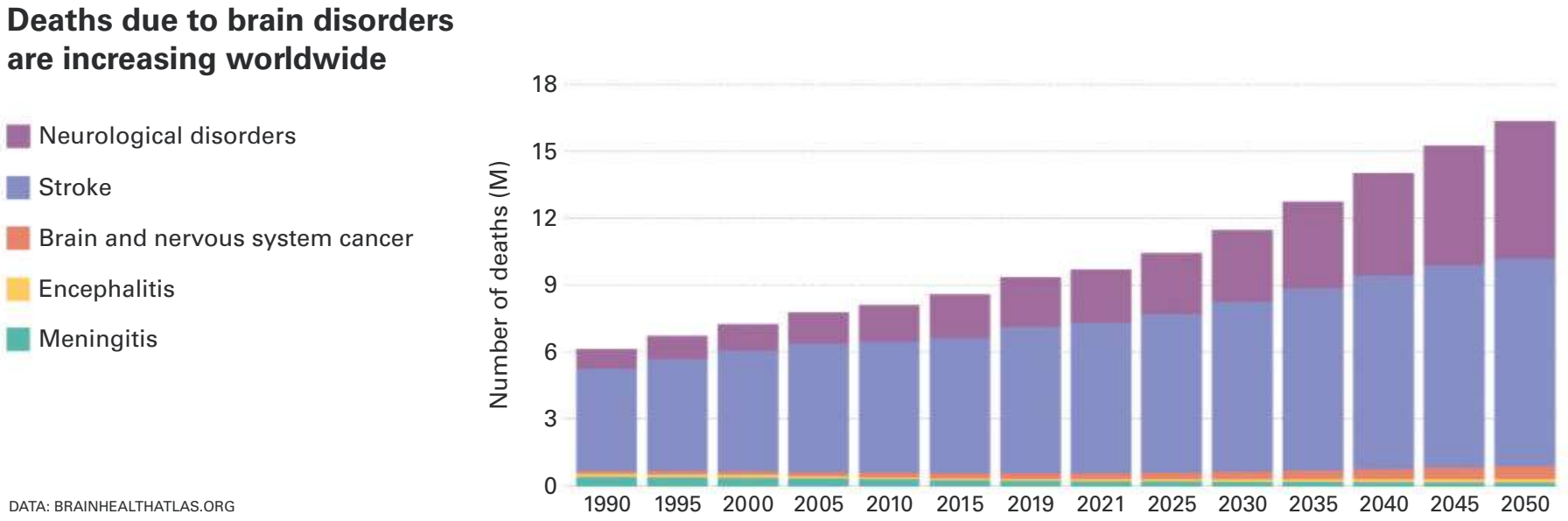
The numbers associated with the human brain are staggering. Each of us has around 86 billion neurons, fed by blood vessels that would stretch four times around the Earth if laid out end to end. Those neurons are networked by around 100 trillion connections.

But just as staggering are the numbers related to brain disorders. These disorders are associated with more than 18 per cent of all health loss around the world. The number of people with dementia increased by 161 per cent between 1990 and 2021. Over the same period, Parkinson's disease cases increased by 273 per cent. Stroke – a condition caused by the brain being starved of blood – is the second biggest cause of death globally. Even if it doesn't result in death, it can be a major cause of life-changing disability.

And the problem is only getting worse. Between 1990 and 2021, the total number of strokes globally increased by 86 per cent. "Stroke is now the number one medical emergency in our accident and emergency departments," says Temitope Farombi, Consultant Geriatric Neurologist at University College Hospital at Ibadan in Nigeria.

All of these issues are set to worsen as the global population ages and the statistics suggest that the world is heading for a huge problem with brain health crisis requiring multiple approaches. "The big challenge with brain health is that it's so many different diseases and every country has a completely different healthcare system," says Michael Oberreiter, Head of Global Access at one of the world's largest biotechnology companies, Roche. The challenge is so large that no single organisation or government can tackle it alone.

That's the problem that Roche, a founding



member of the Brain Health Initiative (BHI), aims to solve. Started in collaboration with the Institute of Health Metrics and Evaluation (IHME), an international public health agency based at the University of Washington in Seattle, the BHI aims to qualify and quantify – with reputable data – the global burden of brain disorders, as well as to improve understanding of the challenge ahead and of the resources needed to drive policy change. Ultimately the goal is to gather and communicate the evidence to inform and shape health policy, to ensure that people with brain disorders get the treatment and care they need. "If you believe that our future lies in having a resilient health system that addresses the needs of all patients, there is no way that we can ignore brain health," Oberreiter says.

Brain disorders are not just a threat to the health of individuals; they also threaten societies. "Brain capital" – an individual's social, emotional and cognitive resources – means that a healthy brain is vital to a thriving population, not only powering our markets and economies, but also defining who we are as people. "Brain health is not just a health system problem: it touches all aspects of society and will continue to do so until we can create meaningful change," Oberreiter says.

The BHI is particularly focused on driving global policy changes because they can bring in lasting and meaningful improvements to those living with brain disorders. One key is to provide policymakers with relevant, actionable information. The current lack of such data is what led to the creation of the Brain Health Atlas, a free online mapping and data tool on brain-disorders, offering a wealth of insights into countries, decades, brain disorders and the social and economic burdens they are causing.

The base-level information comes from a global database of scientific evidence, mostly derived from the Global Burden of Disease study. This collects data on 369 diseases in more than 200 countries via a consortium of more than 11,000 researchers, who publish the study in The Lancet.

Data from the Global Burden of Disease study on brain health is sifted out of this by IHME's network of health and policy experts. This network provides the foundation for the BHI's other key offering: collaboration. Whether within a region or across continents, everyone involved knows the importance of sharing the task of challenging the growth of brain disorders. "National research is very important, but we also need to have cross-country research," Oberreiter says.

"The Brain Health Initiative is focused on driving global policy changes"

That's because every country has a different healthcare system. Only with international collaboration and data-sharing can researchers compare the efficacy of different approaches, and identify the interventions that really make a difference in people's lives.

Such insights, gathered and shared in the right way, are key to persuading decision-makers to act: it gives them everything they need to make the case for policy change. That includes economic information – always a powerful persuader. Preliminary estimates on the Brain Health Atlas show, for instance, that care for people who live with brain disorders cost the global economy over $1 trillion in 2019 and an additional $1.66 trillion was lost in income by those living with brain disorders. If policymakers want a thriving, healthy, productive population, they must pay attention to brain health.

But the issue is getting worse. In Japan, the total number of deaths due to Alzheimer's disease and other dementias has increased by 368 per cent since 1990; Alzheimer's disease now ranks as the country's top cause of death. Nigeria, meanwhile, can expect eight times as many lost years of healthy life in 2050, in a population that will have little more than doubled.

Farombi is not surprised. "We are seeing people coming down with stroke in their thirties or their early forties – it's getting towards a pandemic level of stroke in young adults," she says. "That is going to cause a lot of disability in life here."

All of this will be addressable if projects like the Brain Health Initiative get traction and take-up. So far, things are looking good, Farombi believes. "I'm optimistic because the World Health Organization and major health organisations are now talking about it," she says. "They can use their platform to talk to governments of different nations so that we can all come together and take action."

Oberreiter is also hopeful. He recently attended an event run by the European Brain Council where brain health issues were very much in the spotlight. "It brought the smartest brains from around the world together to discuss the advances we need to make," he says. People are beginning to appreciate that there is a huge potential return on investment to society from interventions in brain health. It's time to move past discussion and take tangible next steps in solidifying global efforts to tackle the growing brain health crisis.

More at: www.brainhealthatlas.org

A world of wars

With global peace still a distant dream, our need to understand conflict remains as urgent as ever. **Jeremy Hsu** explores a powerful synthesis of the explanations

AFP VIA GETTY IMAGES

The devastated area in Gaza around Al-Shifa hospital in April

Book

Why War?

Richard Overy

Pelican (UK), W. W. Norton (US)

RUSSIA'S invasion of Ukraine, Israel's military incursions in Gaza, civil wars in Sudan and Myanmar, tens of thousands killed, millions displaced and global military spending standing at $2.4 trillion in 2023 alone.

This persistence of war both defies and demands explanation. Many have tried. Albert Einstein felt driven to seek an (ultimately inconclusive) written exchange with Sigmund Freud on the subject, published as *Why War?* A number of books have since shared this title, the latest by historian Richard Overy.

Overy warns readers not to expect a comprehensive history of wars or grand arguments about whether humanity has become less violent over time. Instead, he explores the explanatory paths taken by evolutionary biology, psychology, anthropology, ecology and social science in seeking motivations for war, with chapters on resources, ideology, power and security. The result is an excellent primer on the scholarship of war.

Starting with biology, studies of chimpanzees and modern hunter-gatherers shaped a nuanced view that "violence and cooperation are not opposites but two elements of an evolutionary package… to produce survival and reproductive benefits". For Overy, this aligns with the "evolution of a psychology for warfare" as a universal human adaptation.

Elsewhere, early attempts by psychoanalysts to explain war as "an act of collective insanity" proved a dead end. But Overy recognises social psychology's role in explaining how both hunter-gatherers and industrialised nations can dehumanise their opponents to the point of engaging in corpse mutilation, massacres and even genocide.

Many anthropologists viewed modern humans as descending from more egalitarian and peaceful ancestors. That view, says Overy, has been undermined by archaeological evidence of skeletal trauma such as embedded projectiles and cranial injuries, and sites with clues that suggest massacre and cannibalism.

"Environmental crises and climate shocks may have sparked some wars in China's history"

As for environmental crises and climate shocks, Overy notes that ecologists have investigated how these may have sparked wars in China's history, and spurred conflicts between hunter-gatherers and horticulturalists in western North America, between AD 800 and 1350. But he also says that global cooperation can reduce the risk of climate wars.

Looking to the contribution of social scientists, Overy starts with resources. He recounts how the prospect of material gains propelled Viking raiders and Roman legionaries alike to loot cities and enslave populations, while the struggle to control oil production was a factor in several major 20th-century conflicts.

Yet Overy sees the difficulty of separating ambition for resources from other motivations, such as religious belief. While this doesn't always lead to violence, the history of Christian crusades and Islamic jihads or Europe's wars between Catholics and Protestants shows this kind of belief "can be a primary driver that cannot by any measure be rationalized away".

Many modern political scientists and historians have focused on viewing war through the prisms of power and security. Such discussions include the so-called Thucydides Trap that describes how transitions between ascendant and waning powers can lead to war, as in the case of ancient rivals Athens and Sparta. Overy recounts how scholars have fiercely debated whether this applies to China and the US now, although he rejects it as "at best premature, at worst an ill-considered provocation".

Overy also covers the security dilemma that describes how one group's sense of insecurity can spur a preventive or preemptive war that, in turn, increases insecurity. Researchers have offered sometimes conflicting analyses of how Russia's invasion of Ukraine and confrontation with NATO may fit that framework.

More ominously, Overy identifies the hubristic warmongering of leaders such as Alexander the Great and Adolf Hitler as the most unpredictable and dangerous cause of war, describing Vladimir Putin's territorial grab in Ukraine as fitting into that category.

Given that wars will be part of our foreseeable future, we need to better understand why. This book is a great place to start. ▮

Making it all add up

A sometimes fascinating book by a stand-up mathematician leaves **Chris Stokel-Walker** in an unexpected bind

Book

Love Triangle
Matt Parker
Allen Lane

WRITING a popular science book that lures readers into often dense and difficult subjects isn't a task for the faint-hearted. And Matt Parker, the best-selling author of *Humble Pi* and *Things to Make and Do in the Fourth Dimension*, should know all about that. He is, after all, one of an elite few who make it look effortless. Imagine my surprise, then, at finding his latest book, *Love Triangle: The life-changing magic of trigonometry*, hard-going.

I am, presumably, the target reader for Parker's book: an eager learner, keen to fill gaps in my knowledge (which stops dead at my 18-year-old self's studies of advanced mathematics) with witty pop-science books.

I think the problem is that, for all its strengths, at times the book didn't quite offer me the easy catch-up I was hoping for. The introduction raced by with the tale of a speeding driver citing Pythagoras in an Australian court case to explain why they weren't to blame (they lost). The first chapter was similarly speedy, involving hot-air balloons and a pig stampede (yes, really), but was sometimes near-impenetrable.

Parker's frenetic writing style is like a friendly adult firing out facts to their particularly curious 8-year-old charge. It is chummy, engaging and full of exclamation marks! At times, it is very funny – as you would expect from someone billed as a stand-up mathematician.

But facts flew past me at quite a pace, and statements were made without explanation, such that I wanted to reach into the pages and beg Parker to stop so I could ask questions (of which I had plenty).

For example, we learn that the wake behind a duck, no matter its size, always forms an angle of 39 degrees, and that when a doodlebug digs sand traps to catch ants, it builds walls at 34 degrees. The duck story "tells us something about the way waves move in water", writes Parker, while that 34 degrees tells us something about the nature of sand.

But to find out what exactly, we have to wait for the conclusion 270-plus pages later, when we are fobbed off and told that Parker has run out of space to explain it all.

About halfway through the book, after another chapter where I half understood most of what I read, and was completely lost for about 10 per cent of it, I began to wonder whether I was the problem. Was this book just too hard for me?

It is something that I imagine Parker, a former primary school maths teacher in Australia, wouldn't have wanted his reader to feel. But it is a valid question. In my defence, I lapped up Alex Bellos's *Alex's Adventures in Numberland* when it was published in 2010, and have since enjoyed other popular mathematics books, such as Michael Brooks's *The Maths That Made Us*.

Maybe *Love Triangle* is slightly too advanced for those trying to dredge up half-remembered lessons from over 20 years ago. It is a shame because there are many great nuggets in the book.

For example, I was wowed when I read that 3D printers represent the items they create in triangles. And I laughed mightily when Parker got a friend to try to recreate the soccer ball seen on UK road signs to indicate a nearby football stadium – it turns out to be geometrically impossible to make without making some very strange fixes.

So there are very good reasons to persevere with this book: when it clicks, it is glorious. It is clear from reading *Love Triangle*'s 352 pages that Parker knows his stuff. I did pick up some information, and generally found the book interesting and sometimes fascinating.

Regretfully, though, I don't think I understood trigonometry anything like as much as Parker might have liked. And that is a shame.

Chris Stokel-Walker is a writer based in Newcastle upon Tyne, UK

A duck's wake always forms an angle of 39 degrees. But what does that say about waves?

COLIN UNDERHILL/ALAMY

New Scientist *recommends*

Rowan Hooper
Podcast editor
London

The Hayao Miyazaki film **Spirited Away** doesn't have huge amounts to do with science, nor does a stage adaptation of it at the London Coliseum. But the latter left me struck that this story

of a fantastic parallel world does explore our connection with nature, language and our sense of self. It is a bit of a stretch, but you could even say it considers the role of the microbiome when the show's hero, Chihiro (pictured), starts to fade away because her microbiome isn't adapted to the new parallel world.

Miyazaki has always been concerned with ecology, and he shows what happens when rivers become polluted. As one character puts it: "Ugh, humans stink!"

The show is stunningly realised, but most of all, Miyazaki's extraordinary imagination shines through. If you can't get a ticket, do catch the film on Netflix.

I am also enjoying Zoë Schlanger's book **The Light Eaters**, which is almost Miyazaki-like in its storytelling about plant intelligence.

JOHAN PERSSON

Free your inner wild

We weren't built for domestication and must release our wild side. **Graeme Green** is intrigued by the message of a passionate new book

Book
Amphibious Soul
Craig Foster
Thorsons

MY OCTOPUS Teacher won the 2021 Oscar for best documentary and struck a nerve with audiences worldwide. Gently immersing viewers in the underwater world of a golden kelp forest off the coast of South Africa's Western Cape, directors Pippa Ehrlich and James Reed told the story of Craig Foster, a South African film-maker who developed an emotional connection with an octopus, which helped lift him out of a period of depression and burnout.

Foster's new book, *Amphibious Soul*: *Finding the wild in a tame world*, is part memoir and part manifesto. It expands on the film's central idea that humans have lost their sense of connection to plants, other animals and the environment. This is to the detriment of our physical and mental health. "For 300,000 years of human history," he writes, "we lived in accord with nature, as free as any other animal." But the past 10,000 years of settled life, increasingly indoors and separate from each other and nature, was bad for us, leaving "our wild intuition… deeply buried inside".

Foster seems to be an obsessive character. Early on, he admits he is a workaholic, with 16-hour stints in the editing suite costing him his first marriage and threatening his second. While *My Octopus Teacher* suggested a man working through a mid-life crisis, *Amphibious Soul* hints at a longer-running malaise, as Foster seeks solace in nature, even swimming into a crocodile's lair to get a "hit" of wildness.

He is a firm believer in the restorative powers of cold water, not just swimming and freediving without a wetsuit in cold Atlantic waters, but sinking himself in iced water in his freezer, even though it sometimes makes him ill. Despite the debate about the long-term benefits and dangers, Foster is evangelical: daily exposure to cold water and wild animals "lets the primal mind know it's alive, stimulating and strengthening the immune system".

Inspired by the San hunter-gatherers of the Kalahari desert, Foster also writes about "tracking", a process of looking closely at a landscape and learning to read the signs left by wild animals. He calls himself a nature "detective", identifying questions or mysteries, then trying to solve them.

"Foster is right to argue our detachment from the natural world is leading us to destroy wildlife and the planet"

He observes a giant clingfish above the ocean surface moving up towards a limpet clamped onto a rock. "In a fraction of a second, as a large wave cannoned up the rock, the fish grabbed hold of the limpet in its large teeth and twisted its muscular body about a hundred degrees. The clingfish surfed down the rock and in one gulp of its massive mouth swallowed the limpet, shell and all," he writes. "I'd been a witness to the secret behavior of an air-breathing, wave-surfing superpredator!"

As well as including his own "tracking" photographs in the book and a QR code linking to video clips he has made of his encounters with wildlife, Foster's final chapter helps us explore our local environments. We can, he says, reconnect with nature by revisiting the same spot – whether it is a pond behind our home, a nearby park or a hiking trail – and recording what we see.

Enthusiasm aside, there are flaws. I would have appreciated more context and deeper exploration of the subjects that Foster raises beyond his personal experiences, such as rising levels of anxiety, stress and depression in modern societies, the pitfalls of technology and the benefits of spending time in nature.

Science-minded folks will also raise an eyebrow at Foster's belief that the San can merge their minds and bodies with the animals they track. When his friend and colleague Ehrlich reports she once experienced being inside the consciousness of a southern rock agama lizard, Foster writes: "I knew this was an authentic experience." I am more sceptical. Foster's references to "the wild god within" and our "original mother" also have a whiff of woo-woo about them.

But he is right to argue that our detachment from the natural world is leading us to destroy wildlife and our planet. There is a compelling message at the heart of the book about the benefits of keeping "our curiosity bubbling" and connecting with nature, one likely to prompt readers to consider how to get more wildness into their own lives.

Graeme Green is a writer based in Derbyshire, UK

We can track a landscape and spot signs of the creatures living there

ZIGA PLAHUTAR/GETTY IMAGES

Editor's pick

It's just a chip off the old block universe

8 June, p 10

From Hugh Miller, Brighton, East Sussex, UK

Your look at the development of a strange idea from the 1980s, that time may be a quantum illusion, took me back to Karl Popper's essays on the ancient Greek Pre-Socratic philosophers, in particular Parmenides and his block universe, in which he said past, present and future co-exist.

To me, Parmenides's idea was a thought experiment where he stepped out of the world, looked back and, as with the contemporary version, was also "a truly external observer" and "would see a completely static, unchanging universe", though he couldn't have known it thus in our modern terms.

I think the strange and wondrous idea you reported on, and the experiments to test it, would have pleased such great thinkers.

Simulated cosmos could explain rather a lot

Letters, 1 June

From John Bell, Berkhamsted, Hertfordshire, UK

Bernd-Juergen Fischer rightly points out that a simulation of the universe would only need to take account of the inner world of the subjective "I" and whomever and whatever they interact with.

Taking that concept further, most of the universe would need only be stored as a vague set of probabilities, which would only have to be set in stone as subjective reality when the "I" observes something. Wait a minute, that sounds familiar!

More benefits from using wood in your home

8 June, p 24

From Helen Taylor, Chilton, Durham, UK

Graham Lawton writes that wooden buildings don't give off heat like brick buildings after soaking in warmth all day.

But I have seen an effect. In winter, I put the heating on after the house has dropped to around 12°C (54°F). The room temperature stagnates at 16°C (61°F) for about 2 hours. After several winters, I have worked out that the furniture is soaking up the heat: the oak table and sofa warm up by up to 6°C (11°F) in those hours. They feel warm to the touch. Once this has happened, the room rises to my set 18°C (64°F). The next morning, those items feel cold, but the room is still at 16°C – they give off heat at night. Saves me a fortune!

Direct air capture is a dead duck for climate change

25 May, p 12

From Martin Gellender, Brisbane, Australia

Your recent analysis of the potential wider use of direct air capture to remove carbon dioxide from the air is right to be circumspect about its prospects. This would be the most expensive, inefficient and convoluted way to avoid climate change.

How time dilation could affect the quantum realm

1 June, p 32

From Daniel Putman, Westminster, Colorado, US

When it comes to the idea of retrocausality in the quantum realm, how does time dilation affect entanglement? If you sent one of a particle pair much faster than the other and then measured one of them, would this affect the other particle immediately, whose time goes at a relatively different pace? If so, it would seem to be another way of affecting the past.

Extra potassium in the diet isn't for everyone

8 June, p 32

From Geoff Fletcher, Melbourne, Australia

I started using low-sodium "heart" salt about four months ago, having read about its effect on reducing blood pressure. I am in my 70s and I have regular blood tests. After a test five weeks ago, my doctor was concerned about high potassium levels in my blood, so I told him what I had been doing.

I take amlodipine/valsartan to control my blood pressure, which apparently helps the body store potassium. If you are also consuming potassium chloride in salt, this can lift potassium to dangerous levels. I stopped using the "heart" salt immediately and my potassium levels have returned to normal.

Thinking without words is indeed possible

Letters, 15 June

From Faith Anstey, Dalguise, Perth and Kinross, UK

David Werdegar says language is necessary for thought. Long ago in this magazine, a reader posed the question: "Do you think in language?" The consensus was: "No, I think in thoughts." Never mind hominids, chimps have thoughts such as those we would word as "If I crush these leaves into a sponge, I will be able to use it to collect water from that hollow." That is language-free thought.

It's hard to say what has consciousness

8 June, p 28

From Anthony Castaldo, San Antonio, Texas, US

Your review of Christof Koch's new book on consciousness says he believes that AI has little or no causal power – only the imitation of it. I would say it is incumbent upon somebody claiming that what appears to be causal power is actually only an imitation of it to have to prove or cite some distinctive rule as to what is an "imitation" and what is "real".

What makes our causal power "real" and something that appears to be the same kind of power an "imitation"? This seems like a way to avoid defining consciousness. Does it mean a person who is "locked-in" has no consciousness? After all, they have no causal power. Consciousness clearly can't depend on "causal power".

And a vote in favour of Dyson spheres

Letters, 8 June

From Sam Edge, Ringwood, Hampshire, UK

Jim McHardy suggests that advanced civilisations won't need Dyson-style, whole-star, solar energy-collection structures because they will have minimised their energy consumption.

But as far as we know, creating or accelerating matter requires a non-negotiable amount of energy (given by $E=mc^2$ and $E=\frac{1}{2}mv^2$, where m is mass, c is the speed of light and v is velocity), as does exchanging detectable non-random information.

If aliens want to create exotic materials, send themselves or their machines between stars or just communicate with the neighbours over interstellar distances, they will need all the energy they can harvest. ▮

For the record

▮ The photo of the "arch" of the Milky Way (15 June, p 26) shows Passo Giau in Italy and was taken by Andrea Curzi.

▮ The correct graphic for the solution to BrainTwister #23 (15 June, p 47) is available at shorturl.at/jH7In.

Want to get in touch?

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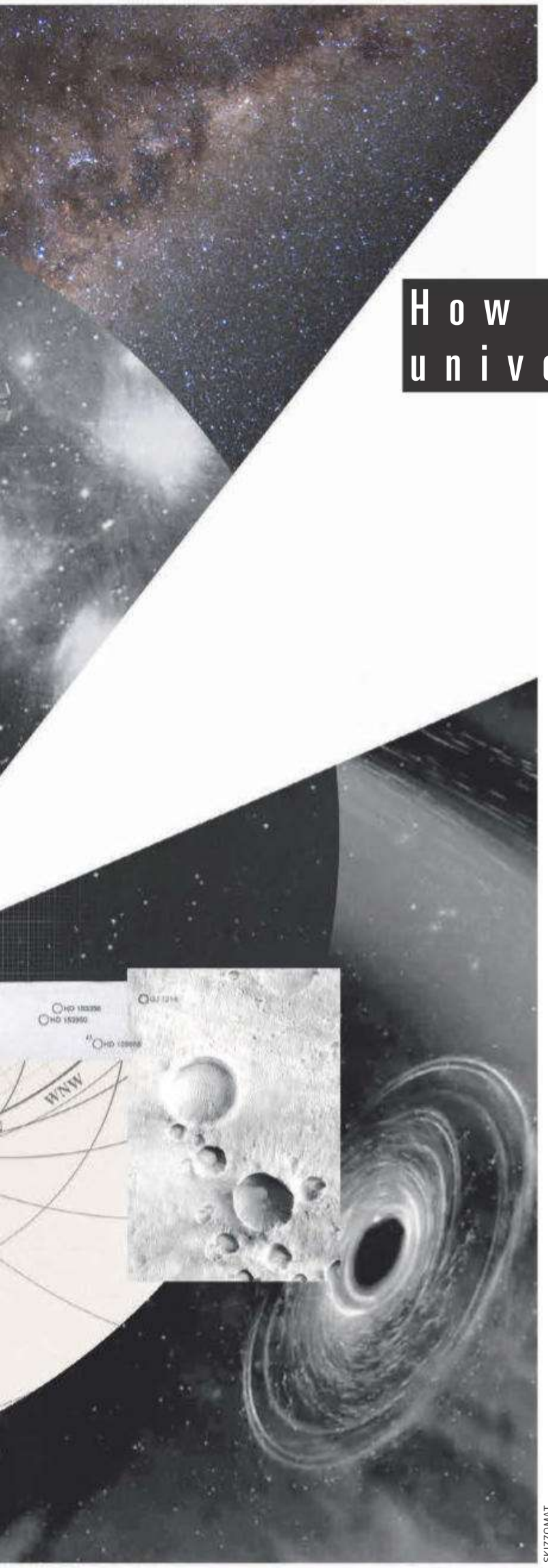
A cosmic perspective

ONE hundred years ago, astronomer Edwin Hubble announced his discovery that the spiral nebula known as Andromeda was actually a galaxy of its own, completely upending our understanding of the scale of the universe. Before this revelation, we thought our galaxy was the only one. Now we know it is just a speck among hundreds of billions of others.
Talk about a perspective shift.

Over the next nine pages, we celebrate Hubble's discovery with a deep dive into the cosmos as we know it – and as we don't. Through nine questions, from the merely intriguing to the existential and the utterly bonkers, we are going to launch you headlong into an invigorating version of the Total Perspective Vortex imagined by Douglas Adams in *The Restaurant At the End of the Universe,* a machine designed to force us to confront the staggering vastness of the cosmos and our place in it.



SKIZZOMAT

How big is the universe, really?

IN a sense, we are at the centre of the universe – but only because we can see the same distance in every direction, giving us the perfectly spherical observable universe. The speed limit of light combined with the inexorable expansion of the cosmos means that we can see about 46 billion light years in every direction. What lies beyond this horizon? That is a mystery we may never solve.

But there are clues. Two competing effects govern the overall size of the universe: gravity and dark energy. All matter has mass, which causes gravitational forces that pull everything towards everything else. To their surprise, however, cosmologists in the early 20th century found that distant galaxies seem to be hurtling away from us. The mysterious force causing this strange expansion of space was dubbed dark energy, and its nature remains elusive to this day.

"Up until the discovery of dark energy and the acceleration of expansion, the universe was simpler," says cosmologist Wendy Freedman at the University of Chicago. Without dark energy, the universe would be much smaller and its size easier to predict.

Even with dark energy, the universe may only be slightly larger than what is observable. In March, Jean-Luc Lehners, then at the Max Planck Institute for Gravitational Physics in Germany, and Jerome Quintin at the University of Waterloo in Canada published a model that suggested the period of rapid expansion right after the big bang, called inflation, could have been even shorter than we thought. This would leave the universe smaller than many other models predict. "In principle, the universe could be just the size we observe, but that would be a hell of a coincidence," says Quintin. "It's more likely that it's at least a couple times that size. In theory, anything between an infinite universe and a relatively small one is possible."

That brings up a truly mind-boggling question: is the universe finite or does it go on forever? In an attempt to answer this, cosmologists look at the shape of space-time. To wrap your mind around this idea, it is simpler to think of space as being two dimensional. There are three possibilities: the universe could be flat like a sheet of paper or more like a sheet of rubber, bent into either a saddle shape or a balloon. If space-time is shaped like a balloon, it must be finite, but the other two shapes can be either finite or infinite.

So far, most experiments show that the curvature of space-time is extremely close to zero. This hints that the universe is flat. But proof may not come for decades because it relies on measurements of positions and movements of distant galaxies taken with an extreme level of precision that isn't yet possible. It would then take a different sort of measurement, looking at the specifics of how different areas in space-time are connected, to determine whether the cosmos is finite or not – far from an easy task. "I don't know if we'll ever be able to tell whether we live in a finite or an infinite universe," says Quintin.

Nailing down the size, shape and history of the universe is crucial for determining its fate. In a balloon-like universe, cosmic expansion could eventually slow and reverse, ending in a "big crunch" – and potentially another big bang. A saddle-shaped cosmos would keep expanding forever, resulting in either a "big rip" – where the expansion rends space-time itself – or the heat death of the universe. The latter is also the most likely fate of a flat universe, wherein everything gets further apart and more diluted, until all that is left is a hint of weak radiation that lingers, unchanging, for eternity.

Leah Crane

Where do space and time come from?

WE tend to think of space-time as the underlying structure of the universe. But whether it really is fundamental or emerges from something deeper is a question that keeps physicists up at night. "It's not just a philosophical question that you discuss over a beer," says Marika Taylor at the University of Birmingham in the UK. "It is actually something that comes into the calculations that people do."

The best place to start is quantum mechanics, which describes the behaviour of subatomic particles. Famously counterintuitive, one of the theory's core tenets is that connections between particles can transcend our usual notions of space and time. This happens via a phenomenon called entanglement, in which particles can affect each other's properties even when they are half a universe apart.

Cosmologists now generally accept that entanglement is intimately linked to the emergence of space. If we know the degree of entanglement between two quantum particles, we can derive the distance between them. Do that for a network of many particles and you start to form a geometry from which what we call space can emerge. Perhaps, then, space emerges from quantum entanglement.

What's more, advances in string theory, a candidate for a theory of everything, say that the goings-on in space can be fully described by data held on the outer surface, or boundary, of that space, a phenomenon known as holographic duality. Put that together with quantum entanglement and you can build a universe that boasts spatial structure: distances and geometry.

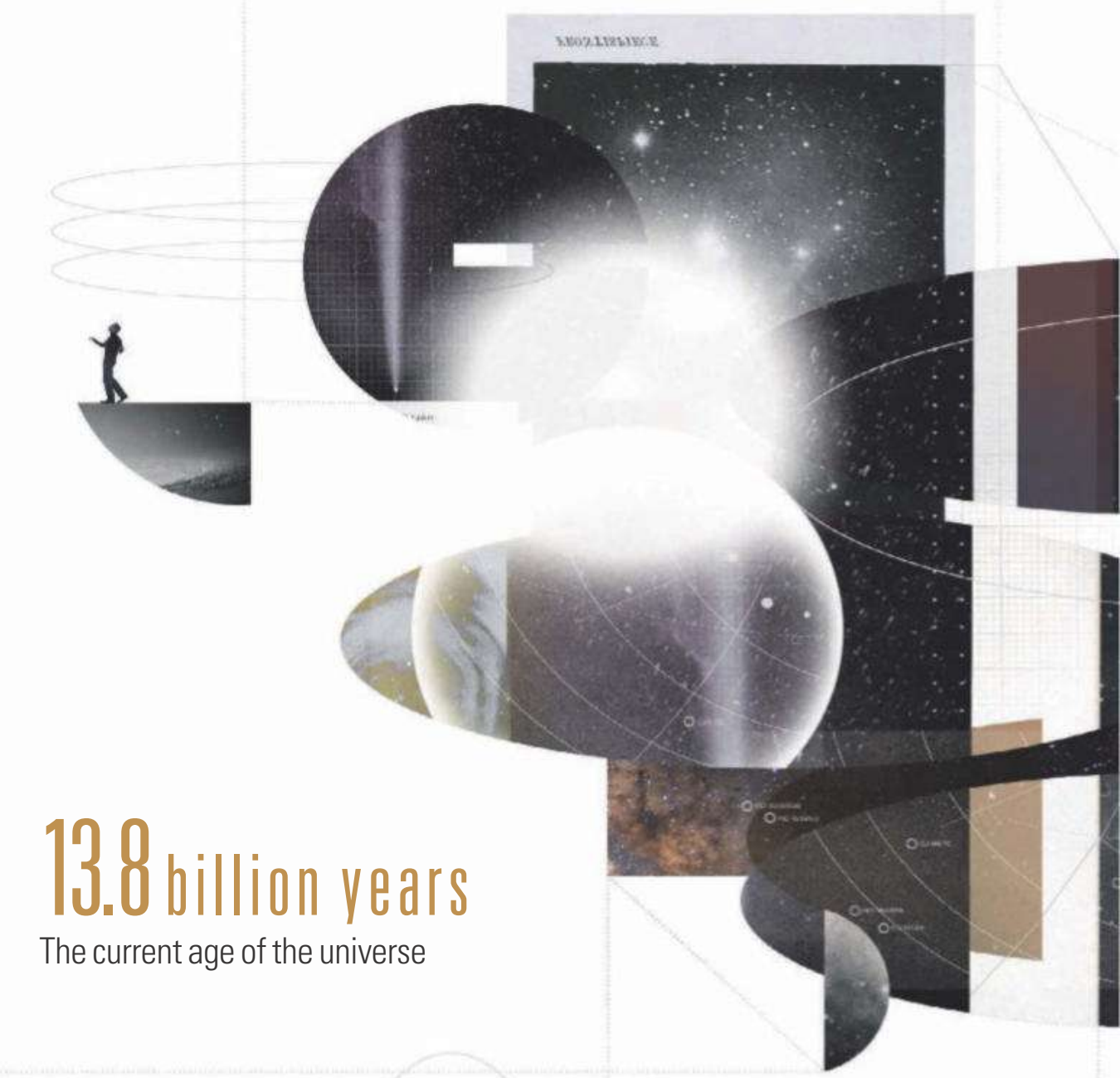
Spyridon Michalakis, a mathematical physicist based at the California Institute of Technology, has worked with Sean Carroll at Johns Hopkins University in Maryland and Charles Cao at Virginia Tech to build an intriguing explanation of space-time's origins. Entanglement between particles on the boundary of space-time gives rise to a particular "distance", the idea goes, and the entanglement distances translate into "geodesics", or the trajectories followed by particles as they move through the universe. These geodesics build a geometry to space-time, something like the curved geometry that Albert Einstein's general theory of relativity says lies behind gravity. "Entanglement becomes curvature, and that curvature can be thought of as geometry," says Michalakis.

Yet this doesn't answer the fundamental question. Saying space and time arise from the boundary surface of space-time is just kicking the question down the road. "We haven't, in a deep sense, explained why space should exist," says Taylor.

The answer might be something completely different. That is certainly what Chiara Marletto at the University of Oxford thinks. She works with her Oxford colleague David Deutsch and others on "constructor theory", which aims to express the laws of physics in terms of which transformations of a physical system are possible, while boiling everything down to quantities of information. Because the universe seems to run as a kind of information processor, constructor theory seeks an information-based take on the origins of space. "We would say that time is not fundamental, and space-time is not fundamental either," says Marletto. Such ideas remain a work in progress, though.

A deeper understanding will come through the study of cosmological phenomena such as black holes and the singularity at each one's centre, says Taylor. "The whole notion of space-time breaks down there, and understanding how it breaks down is intimately linked to the question of how it emerged in the first place," she says. "We know that things are going crazy there. Once we understand that, we can flip it round and see how the three spatial dimensions actually emerge."

Michael Brooks



13.8 billion years

The current age of the universe

Do we live at a special time in the universe?

SINCE the opening act of the universe 13.8 billion years ago, a diverse set of characters have trod the boards – stars, planets, moons, quasars. But if you tend to get fidgety at the theatre, there is bad news: this cosmic performance has at least 100 billion years to go. Which raises a question: are we living at a special moment – the cliffhanger before the interval – or is this just an inconsequential moment in the mid-plot?

One hint that this is a special instant involves a swathe of observed properties of the universe known as fundamental constants. These include the strength of gravity, for example, and the fine-structure constant, known as alpha, which determines the way matter and light interact and thus how stars burn. If these numbers were just a shade different from how they are, then life might be impossible.

Why is it all so perfect? One possible answer is that these constants aren't so constant. Perhaps they have been gradually changing over the life of the universe and we happen to live at an auspicious blip in time. John Webb at the University of Cambridge has spent decades investigating this idea, in his case in relation to alpha. Based on precision measurements of the cosmos, Webb has claimed in the past that alpha has indeed morphed – although he now thinks those claims were wrong, thanks to systematic errors in the instruments used to gather data. "The existing measurements are close to meaningless," he says.

Webb is optimistic that with artificial intelligence and new instruments, like the James Webb Space Telescope, it won't be long before he has reliable data. However, it must be said that most physicists thumb their nose at the idea that the constants of nature have changed – and at the general notion of our universe being special. Alexander Vilenkin at Tufts University in Massachusetts has suggested that we follow the "principle of mediocrity" and assume that there is nothing particularly special about us.

Still, there is a simpler sense in which we live at a special moment in cosmic history. Life as we know it couldn't have formed before there were stars to fuel it and planets at a suitable distance from their star on which it could develop. Life also couldn't arise as soon as stars appeared, because it requires elements heavier than the hydrogen and helium that made the first stars to support complex biochemistry. "Several generations of stars are needed to build these [heavy elements] up to a level where you get planets and the chemistry of life," says Geraint Lewis at the University of Sydney, Australia. That means at least a few billion years after the big bang.

Being intelligent enough to appreciate this also requires special conditions, says Lewis – and they are fast disappearing. That is because significant intelligence seems to take billions of years to develop – it did on Earth – and the star formation that can support it is slowing. Intelligence-supporting stars won't be around for that long, relatively speaking. "More than 95 per cent of the stars that will ever exist have already been born," says Lewis. "Star formation is winding down: in the future, stars like the sun will become rarer and rarer."

In 100 trillion years, all stars will have died and the chances of habitability as we know it will have dwindled to nothing. That is the end of the show. Cue infinite darkness.

Practically speaking, we don't even have that long. Before then, the mysterious repulsive force known as dark energy will probably drive the universe apart to the point that no light will be able to reach Earth from any other star. Even if life were still tenable, doing astronomy would be impossible. In that sense, at least, we are part of a singular generation of humans who can ask and answer questions of the cosmos. "We truly live in a special time in the life of the universe," says Lewis.

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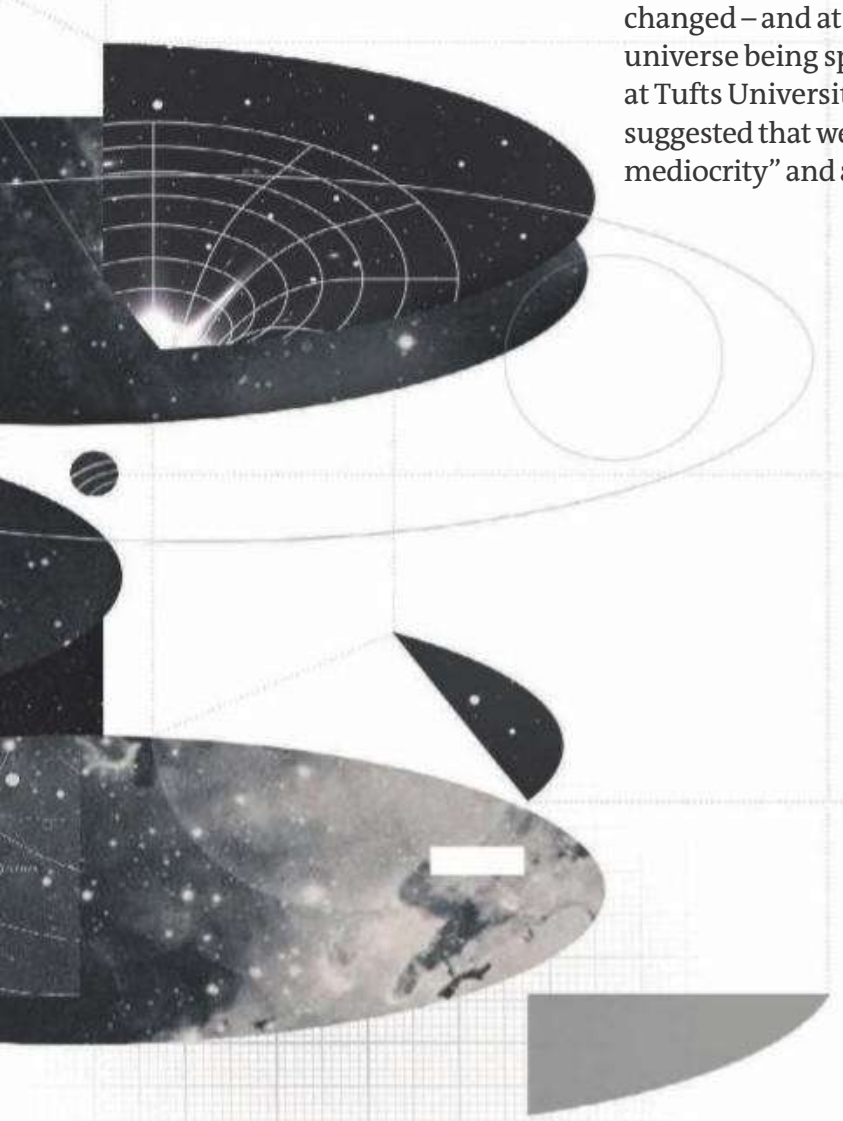


Are we alone?

ALL the life we know of in the entire universe is squeezed onto a tiny rock, floating in a minor arm of the Milky Way. There are billions of other planets with the potential to support life. But what effect does our location have on the prospect of finding it?

So far, our search for life elsewhere has only scratched the surface. "The bubble of space that we've managed to search around our sun is very small compared to the size of the ›

Continued on page 36

YOU ARE HERE

This map shows the circle of the cosmos that surrounds us, extending to a distance of 200 million light years. At this scale, space is comprised of clusters of galaxies and voids, the latter being areas with relatively few galaxies. The Milky Way, at the centre, is part of the Local Group of galaxies, with the Virgo cluster our nearest neighbour.

Cygnus void

Delphinus void

NGC 6769

NGC 6753

Pegasus cluster

Pavo cluster

180°

Local vo

270°

Eridanus void

Eridanus

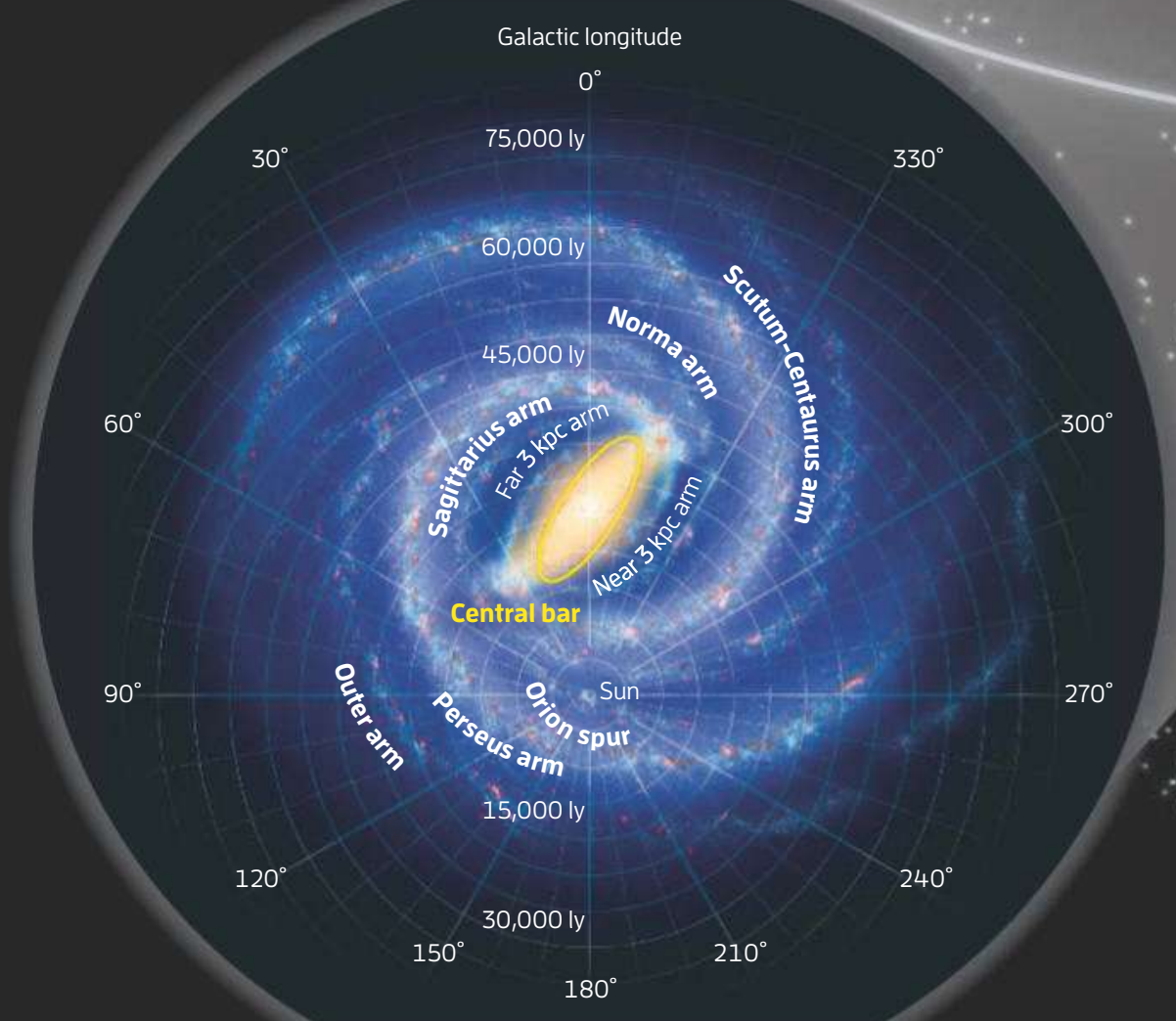
Fornax cluster

0°

Taurus void

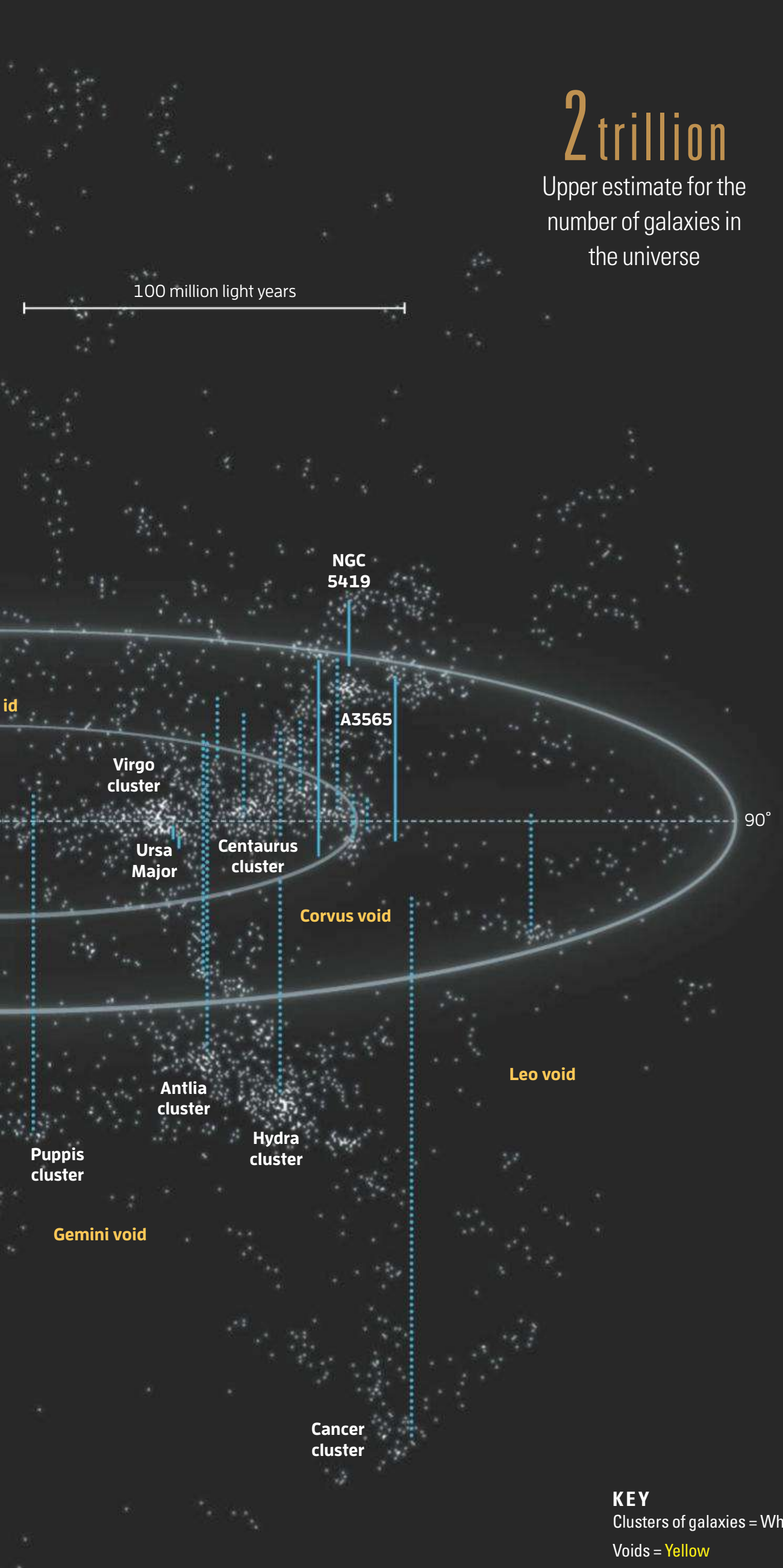
MAJESTIC SPIRAL

The Milky Way's spiral structure is dominated by two main arms called Scutum-Centaurus and Perseus. It also features a dense region known as the central bar. Our solar system lies on a more modest structure called the Orion spur.



2 trillion

Upper estimate for the number of galaxies in the universe



Where are we in the universe?

However tangled the question of our metaphorical place in the universe, we can use astronomy to grasp Earth's physical location.

Earth orbits the sun at a distance of 150 million kilometres and the sun orbits the centre of the Milky Way. Specifically, we are in the Orion arm, around 26,500 light years from the centre (see "Majestic spiral", far left).

The Milky Way resides in the Local Group of galaxies. About 2.5 million light years away is our closest neighbouring galaxy, Andromeda, the largest galaxy in the Local Group. Right now, we are hurtling towards Andromeda at more than 100 kilometres per second; in about 4 billion years, the two galaxies will collide.

That will shake up the Local Group, but it will be barely a blip on the radar of the wider cosmic neighbourhood. The Local Group is on the outskirts of the Virgo supercluster, the larger structure named after our next-door Virgo cluster. The Virgo supercluster itself is one of four parts of an even larger supercluster called Laniakea, which contains about 100,000 galaxies. All of that resides at the centre of the observable universe, which may or may not extend far beyond what we can view (see "How big is the universe, really?", page 31).

There are limits to how well we can orient ourselves, though. There is no way for us to meaningfully move from our place in the universe and observe it from any other perspective. Naturally, that means there are things we can never see. For example, the Milky Way's centre is teeming with stars and dust that obscure about 20 per cent of the sky, an area known as the Zone of Avoidance (or, more accurately, the Zone of Galactic Obscuration). There are ways to peer through this zone, such as observing in radio wavelengths, but a huge swathe of the sky remains blocked out, even to the most powerful telescopes.

There are around 10 million superclusters in the observable universe, at least hundreds of billions of galaxies. We can't possibly study all of them, but we can get a taste of their dazzling diversity in our own humble corner of it.

LC

galaxy," says Jessie Christiansen, an astrophysicist at the California Institute of Technology. Yet we have already found more than 5000 planets circling other stars, called exoplanets. While some of these have been detected across our galaxy – and even in other galaxies – most reside within a few hundred light years of our sun, a stone's throw in the cosmic scheme of things.

Astronomers have begun looking at different types of stars in our galactic neighbourhood to see how they might affect the chances of habitability on the planets around them. We live in an arm of the Milky Way called Orion, which sits inside the main plane of the galaxy, called the thin disc (see "You are here", page 34). We are surrounded by stars within the Orion arm. Further out, on one side we have the overcrowded bulge of the galaxy's dense core, while on the other we are enveloped by the sparser outer parts of the galaxy's other arms.

Thin disc stars, like our sun and others in the Orion arm, are generally rich in metals – which means anything heavier than helium – says Jesper Nielsen, an astronomer at the University of Copenhagen, Denmark. "They have more iron, magnesium and so on."

Stars that reside above and below the plane of our galaxy are said to be in the "thick disc", while those at the outermost edge of the galaxy are said to be in its halo. These stars are typically more metal-poor as they were some of the first to form in the galaxy, meaning there hadn't been enough supernovae, the explosions of stars that create heavier elements, to enrich the galaxy yet.

This is good news for the search for life in our vicinity. Nielsen and his colleagues have found it is much harder to form planets around older, metal-poor stars "simply because there's not enough material around", he says. On the other hand, metal-rich younger stars – like those that surround us – have such an abundance of

4.2 light years

The distance to our nearest star, Proxima Centauri

material that they are able to form a wider diversity of planets, including rocky worlds like Earth and larger planets.

Our place in space may not be a barrier to finding life, but it might make it a lot tougher to communicate with it. The first problem we encounter is the distances involved. It is 4.2 light years to our closest star, Proxima Centauri. If there was intelligent life on one of its planets, sending a signal and receiving a reply would take the best part of a decade. It only gets harder for more distant stars.

For now, the search is focused on Earth look-alikes. A telescope being developed by NASA called the Habitable Worlds Observatory (HWO) is set to launch in the 2040s and has a primary goal to image 25 Earth-like worlds around sun-like stars. "I believe, in our lifetime, something like HWO will see a signal in the atmosphere of a rocky planet in the habitable zone of a star like our sun that we think is life," says Christiansen.

Just as Edwin Hubble's recognition of Andromeda as a separate galaxy in 1924 shifted our perspective of the universe, so too could the knowledge that we aren't the only life in the galaxy. "It might start a revolution in life, religion, philosophy and science," says Christiansen. Or not: "It might be a headline for a day and then everybody just goes back to what they were doing."

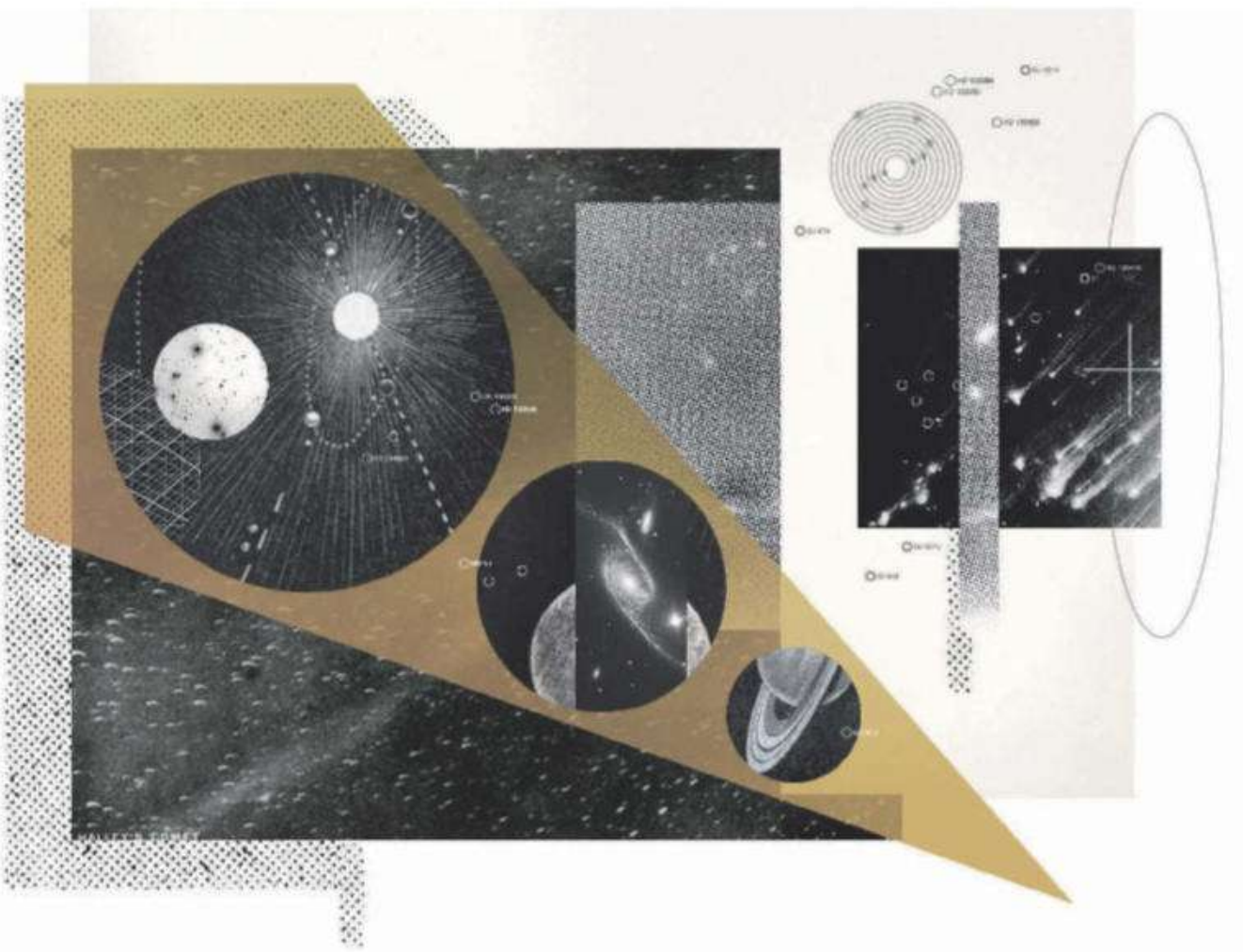
Jonathan O'Callaghan

How should we feel about our cosmic insignificance?

ON a cold evening last October, I went into my garden to gaze at a fuzzy blob in the night sky. Unless you are in the darkest of places, this blob is so faint to the naked eye that it would be easy to convince yourself there is nothing there. I raised my binoculars to my face and an elongated smear with a bright centre appeared. This is the Andromeda galaxy, the most distant object it is possible to see with the unaided eye.

I often look at Andromeda during the winter months. But I specifically chose 6 October 2023 because it was exactly 100 years to the day since Edwin Hubble made his observations that would, just over a year later, lead him to conclude that Andromeda wasn't part of the Milky Way but a galaxy in its own right. As I stood there, I thought about how that light had travelled 2.5 million light years to reach my eyes.

Many people find it frightening to be confronted with the sheer scale of the universe. If we try to grasp the epic distances involved, we can end up feeling very small, as if nothing we do in our puny lives on this tiny planet could ever matter. But there are least two



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reasons why we needn't feel that sense of insignifcance and the dread that can accompany it.

First, contemplating the huge scale of space can give us a healthy sense of perspective. This has certainly been my experience. Since I was a child, when I first learned about the vastness of space, thinking about the size of the universe has brought me comfort. When I have to do something that scares me – like give a talk to lots of people – I take a moment to consider just how big the universe is, and it doesn't feel so intimidating.

I know I share this feeling with others. The journalist Oliver Burkeman has written that he finds this kind of thinking "really relaxing" because "it's a reminder that in the grandest scheme of things, nothing I do or fail to do matters much at all". In his book, *Four Thousand Weeks*, he calls this way of thinking "cosmic insignificance therapy".

The second reason comes from philosphers who have thought deeply about what it means to be cosmically insignificant. "Reflecting on the size of the universe and our smallness within reveals how little power we have over the grand course of things," says philosopher Nick Hughes at the University of Oslo in Norway. "In that sense, we are indeed insignificant, but it would be a mistake to respond to this realisation with nihilism or despair."

He points out that power is only valuable as a means to an end. The ends we care about – things like relationships, justice, the pursuit of knowledge and the creation and appreciation of art – don't depend on us having power on a cosmic scale. "Most of what matters to us is within our grasp."

Hughes says he does feel anxiety when he considers the scale of the universe. "Realising how small we are makes it vivid to me just how fragile our existence really is," he says.

I get that. But for me, feeling small and fragile also reminds me how precious life is, and that I must appreciate every part of it. If I ever lose my perspective on that, Andromeda will be there to remind me.

Abigail Beall

5000

Approximate number of confirmed exoplanet discoveries

Can we ever understand the universe from the inside?

PERFECT it may not be, but science is our best route to objective knowledge. Through observation, experiment and mathematical abstraction, it strives for a third-person perspective, a view from the outside of whatever we investigate. That is perhaps most obvious in physics, which seeks to describe things at every scale. "We take ourselves out of the system to stabilise [it] as an object that we can think about," says Jenann Ismael, a philosopher at Johns Hopkins University in Maryland.

This separation of scientific understanding from subjective experience began in the 16th century, when Galileo Galilei showed it was possible to describe the movement of bodies on Earth and in the heavens according to mathematical laws. And you can't say it hasn't worked. Today, physicists can look proudly upon a vast tower of ideas and equations that closely predict how reality works at almost every level, from the grand narrative of the origins and evolution of the universe to the minutiae of the elementary particles that comprise it.

But in recent years, a growing number of physicists have come to realise that this notion of an objective universe, independent of our experience of it, is an illusion. "We get so excited about our capacity to abstract and extrapolate that we forget that physical models are not reality," says cosmologist Marcelo Gleiser at Dartmouth College in New Hampshire.

That is a problem, he says. We fail to recognise that our subjective experience is part of the universe – that our models are the product of our insider's perspective, rather than a faithful representation of reality – and this can lead us astray.

The flaws in assuming we can have a purely objective perspective are clearest when you consider quantum mechanics, the famously strange set of rules governing the behaviour of subatomic particles. Quantum theory says – and countless experiments have confirmed – that you can only know whether a particle will be here or there, say, when you measure it. Different experimenters carrying out the same single measurement will end up with different results.

"Quantum theory is really screaming at us that observers matter, that facts are relative," says Daniele Oriti, a theorist at Ludwig-Maximilians University in Germany. "The relationship between our minds, our models and the world... it's very subtle."

This calls into question the pursuit of a neat set of equations that describes the universe as a whole, known as a theory of everything. "Let's call it an abuse of power," says Gleiser, whose recent book *The Blind Spot* – co-authored with astrophysicist Adam Frank and philosopher Evan Thompson – argues that physicists' "hubris" about the meaning of mathematical laws is actually preventing us from ›

understanding the true nature of the universe and our place within it. "We must not forget that these tiny characters, we ourselves, are also the authors of the narrative," they write.

Oriti expresses a similar sentiment. "Trying to understand the mind of God is an outdated view of physics," he says. "We can only know the universe from the inside."

The question is, how can we make sense of it from within, without discounting our role in it? For Oriti, it is about making sure that the ways we understand different aspects of the universe, coming from multiple observing perspectives, don't contradict one another. "The best we can hope for is that every [observer], with its own perspective, is capable of determining what is seen from all the other perspectives, by being able to translate between perspectives – and not have anything left untranslatable."

In practice, this means that perhaps we shouldn't think in terms of a single, objective view of reality. Ortiti thinks of reality as intersubjective; it might lie in the information relating different perspectives to one another.

Similarly, Gleiser increasingly views the cosmos from the perspective of "systems thinking", which makes sense of the complexity of the world through the interconnections between parts. He is among those who suspect the key to that could be a better understanding of emergence, where properties that don't seem to exist when we look at the individual components of a complex system

93 billion light years
Diameter of the observable universe

suddenly take shape when we see it as a whole, even from the inside.

This new approach to cosmology would look very different to the status quo, says Gleiser, having more in common with the study of biospheres than black holes. "It's a different ball game," he says.

One thing, at least, has become clear. "If you're asking a question that demands an external view of the universe," says Ismael, "then you're not asking a question that makes sense."

Thomas Lewton

Is the universe conscious?

AN astrophysicist and a surgeon walk into a bar. No, this isn't the start of a bad joke. A few years ago, astrophysicist Franco Vazza met his childhood friend Alberto Feletti, who had become a neurosurgeon. As they reminisced and chatted about their work – Vazza modelling the structure of the universe, Feletti poring over the composition of the brain – a thought struck them: why not compare the two?

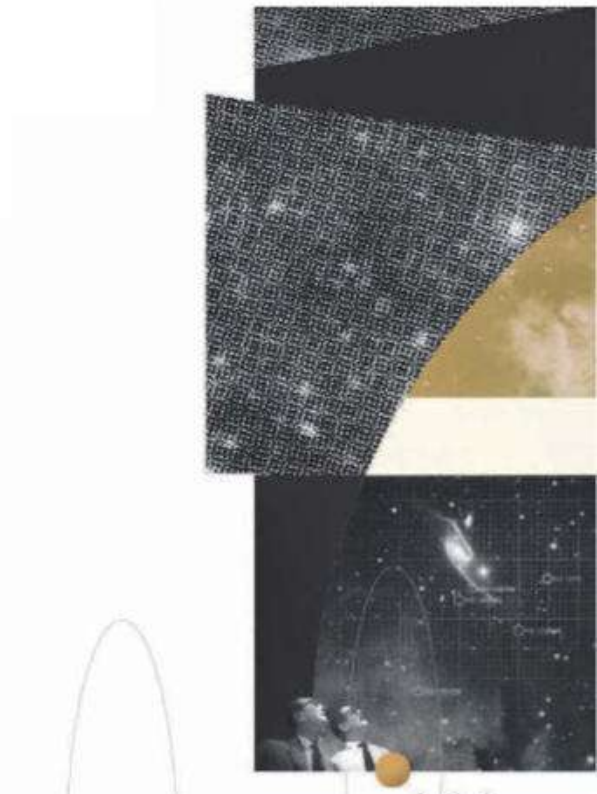
Vazza, based at the University of Bologna, Italy, did just that. He used statistical methods to compare the neurons in one area of the brain, the cortex, with the cosmic web, the pattern of matter distribution across the universe. Vazza looked at the number of nodes in each network and how densely each node was connected. The results surprised him. "It is a tantalising level of similarity," he says. The structures differ in size by some 27 orders of magnitude. But if you ignore that, "the two patterns sort of overlap", says Vazza.

For some physicists, this likeness is too tempting to ignore. Some have even suggested the possibility that the universe "thinks" or is in some sense conscious, an idea with roots in the philosophy of panpsychism.

Traditionally, researchers explained consciousness in one of two ways. Materialists say matter is all there is and consciousness – somehow – emerges from it. Dualists say there are fundamentally two kinds of stuff: matter stuff and consciousness stuff. Much ink has been spilled on the shortcoming of both ideas. For instance, how exactly does consciousness arise from pure matter?

For some, panpsychism offers an elegant middle way. It says that consciousness is a fundamental ingredient of reality, that all matter, including particles, has some form of very basic consciousness. This arguably makes it easier to see how you could explain the way human-level consciousness arises – in the sense that the brain is already built from more basic units of consciousness. "It's definitely having a moment," says philosopher Joanna Leidenhag, who studies panpsychism at the University of Leeds in the UK.

It is an extension of this concept, called "cosmopsychism", that posits the universe is conscious. For his part, Vazza is unimpressed by the idea, on multiple levels. "Consciousness is already something we can't define, so it's pretty weird to attribute it to the universe," he says. The motivation for his study was more to understand how complex networks organise themselves. Plus, just because two things have the same structure doesn't mean they have the same character. A living brain and a dead brain, after all, are organised in the same way. On top of that, the universe is so vast that it would take eons for even light-speed signals to traverse the cosmos: if it does "think", it does so extremely slowly.



In his book *Why? The Purpose of the Universe*, the philosopher Philip Goff suggests a slightly different vision of cosmopsychism. He points out that physicists see particles as manifestations of quantum fields, and thus you could argue that these fields are the basic units of consciousness. Goff doesn't think this necessarily means the universe has the capacity for reflective thought, but he muses on whether this fundamental mind could influence the way the universe evolves over time.

Whether any of this is true is beyond empiricism – at least for now. In any case, maybe the rise of panpsychism says more about society than the universe. "As the industrial revolution happened, nature was conceived as a machine, and when the digital revolution happened, everyone was into metaphors of the brain as a computer," says Leidenhag. But the climate crisis has changed the discourse. "Now we're becoming more ecologically aware, it's not surprising that we're turning to more organicist metaphors," she says.

Joshua Howgego

Is our universe the only one?

WE think our universe contains everything that exists, has ever existed and will exist in the future. But this might not be the case: there are many ways other universes could exist.

One is that we could be a single part of a branch of infinite universes known collectively as the multiverse. These universes might have appeared shortly after the big bang, they might be hiding in extra dimensions or they could pop into existence whenever a quantum property goes from a cloud of possible states to a single reality.

Multiverse ideas gained scientific weight in the 1980s with the invention of inflation, a period when the early universe suddenly expanded. Inflation explains why the cosmos is so flat and smooth, but it also predicts the creation of a multitude of independent bubble universes.

Yet inflation is just one route to a multiverse, and it has its critics. In recent years, many cosmologists have turned to alternatives like cyclic universe theories, which say the universe is on an unending cycle between ballooning and compressing. These theories still invoke multiple universes, but at different times.

"What I didn't like about inflation was that there are very few genuine predictions – you don't get out much more than you put in," says Neil Turok, a physicist at the University of Edinburgh, UK, who helped develop a model for a cyclic universe, published in 2001, as a rival for inflation. "It just struck me that there has to be a better explanation."

The cyclic universe has its benefits. Dark energy, the mysterious force causing our universe's expansion to accelerate, appears much weaker than predictions, which is a problem. It has been suggested since the 1980s that dark energy could reduce over time in a series of "jumps". Then, in 2006, Turok and Paul Steinhardt at Princeton University combined this idea with a cyclic universe. They showed that, as dark energy got smaller, the time between jumps would get longer and longer, so a cyclic universe would naturally spend the most time with low dark energy, making what we see today more likely.

In the hunt for evidence for a multiverse, one place cosmologists are looking is the cosmic microwave background (CMB), the light left over from the big bang. Cosmologist Hiranya Peiris at the University of Cambridge and her colleagues have shown that colliding bubble universes, like those predicted by inflation, should leave

1

Number of planets in the universe known to support life

circle-shaped imprints in the CMB. In 2011, they discovered four patches of sky that may one day reveal such scars. Now, Peiris is involved in a quantum experiment to establish how bubbles of vacuum form and collide – insights that could improve the multiverse predictions. "The thing that needs to be sharpened up is the theoretical predictions," she says. This could strengthen the evidence for the imprints or rule them out.

When it comes to cyclic models, Roger Penrose, a mathematical physicist at the University of Oxford, has suggested signs of these could also pop up in the CMB. Others have said black holes from previous cycles could potentially survive into this universe and be detectable.

For his part, Turok now favours a newer concept called a mirror universe – where time reverses at the big bang – a model he believes simpler than the cyclic universe. And it may soon be put to the test.

A mirror universe could be the answer to the mystery of dark matter, the unknown substance that makes up some 85 per cent of the mass in the universe. The idea is that dark matter could be made up of as-yet undiscovered massive neutrinos, which could be in abundance in a mirror universe. In 2022, a group of researchers showed that this would mean the lightest neutrino has exactly zero mass – a prediction currently being tested in large-scale galaxy surveys such as the Vera C. Rubin Observatory, due to start scanning the universe next year. One hundred years on from Edwin Hubble's proof that other galaxies are out there, we could be on the cusp of finding evidence of another realm beyond our universe.

Miriam Frankel

PAUL RYDING

‘There’s a feeling that overusing antibiotics can’t hurt, but it can really hurt’

Avian flu, the rise of antibiotic-resistant bacteria that spread easily through water and another pandemic are what keeps infectious disease specialist **Jeanne Marrazzo** up at night, finds Charlotte Lytton

WHEN Jeanne Marrazzo was announced as director of the US National Institute of Allergy and Infectious Diseases (NIAID) last year, she became one of the leading public health decision-makers in the world. Replacing Anthony Fauci, whose tenure during the covid-19 pandemic made him a household name, the stakes have never been higher for the agency's newest boss.

Having spent decades working across HIV prevention and sexually transmitted diseases, as well as overseeing therapeutic interventions for covid-19, Marrazzo is now in charge of NIAID's $6.6 billion annual budget – and the future of the US response to infectious disease.

That involves working with the institute's 21 laboratories across the country, leading the fight against ebola and HIV and spearheading efforts to develop new vaccines, therapies, diagnostics and technologies.

At the top of Marrazzo's to-do list is tackling antimicrobial resistance (AMR), or drug-resistant superbugs, which are predicted to cause 10 million deaths per year by 2050 at an annual cost of $1 trillion to the global economy. In May, the UK's former chief medical officer warned that the rise of these pathogens could make the pandemic look "minor" and that the issue is more acute than climate change.

Our warming world is partly responsible for increasing rates of AMR, with shifting climate conditions around the globe helping bacteria such as *Salmonella* and cholera-causing *Vibrio* to survive – and evade our current antibiotic weaponry completely. Here, Marrazzo outlines the things we should perhaps fear most, as well as some promising developments on the horizon.

Charlotte Lytton: In what ways is the climate fuelling the problem of AMR?

Jeanne Marrazzo: When it comes to bacteria, climate change is affecting so many things on a macro scale. It has an impact on the health of livestock, which are often totally overfed with antibiotics and are a huge reservoir of antibacterial resistance. People are relocating more because of the heat – increased human mobility has been linked with greater AMR. And climate change has been linked with more natural disasters, which are particularly concerning because they disrupt clean water supplies and so we see more outbreaks of AMR bacteria in the gut.

> "What if there was something that spread really easily through our water supply?"

On top of that, there are more diseases transmitted from animals to humans. So I think it all sets a stage where we're less and less able to predict even where outbreaks are going to happen – and when they do happen, it becomes harder to respond to them because infrastructure is threatened.

Some 1.2 million people are killed by antimicrobial-resistant bacteria each year. Did covid-19 make things worse?

I would say the pandemic effect can't be underestimated. For one thing, we know that AMR infections in hospitals increased during the pandemic, and that was probably due to a variety of factors.

One is that there were so many ill people who were at risk of hospital-acquired infections and so got treated with a lot of antibiotics. Sometimes they didn't need them, sometimes they really did. The proportion of people I saw who clearly had covid-19 but came in being treated with steroids and antibiotics on the outpatient side was, I would say, 95 per cent.

The other thing is we weren't examining patients as much. The isolation procedures were really very tough, so people often didn't get diagnosed and treated in a timely fashion.

How have things changed in the past decade?

I would have expected to see more antibiotics come through the pipeline into clinical trials in the past decade. But it's very expensive. The return on investment for these products is very, very low.

The other thing I think that we don't talk about enough is the role of biofilms [thin layers of bacteria that gather on hard surfaces]. Biofilms, in particular, are a great place for ›

bacteria to hide, and while you can treat people with antibiotics to kill the bacteria, you often can't penetrate bacteria that are hiding in biofilms. They're often in catheters, intravenous things, valves, so we don't have a lot of ways to eradicate potential stealthy bacteria in those settings. And that's a good place for them to continue to evolve.

Will the situation get worse?
I am worried about antimicrobial resistance. We've had outbreaks, but most of the time we have been able to contain them, whether it's in an institution or in a small population. But what if there's something that was really easy to spread that, say, spread through the water supply? Especially in systems that are disrupted during conflict. You can say "oh, pasteurisation is great", "oh, we have great sewage systems" – unfortunately, that isn't the case in many parts of the world.

Which treatments do you consider to be the most promising?
Phages [bacteria-killing viruses] are very good. I think that's important. I'm also hopeful about the AI models we're using to look at synthesis of new drugs and what compounds might be adapted from products we already know work.

Given the scale of the problem, why isn't there more investment in developing solutions?
The easiest answer is that there's almost no return on investment in these products compared with something like weight loss drugs or cancer drugs. Those are huge markets where people are making billions and billions of dollars. Antibiotics aren't cash cows. There is legislation in the US that is aimed at creating some incentives for pharmaceutical companies to come on board. I'm hopeful that will change things, but it isn't a great scenario.

The more we use antibiotics, the more chances bacteria have to become resistant to them. Do you think that the public fully understands the dangers of antibiotic overuse?
I don't think they do, because you talk to people who have a cold and they say "this is so bad, I finally got antibiotics and it went away". The reality is it probably would have gone away anyway because it wasn't bacterial to start with. There is this feeling that it can't hurt, but it can hurt. It really does hurt to overuse these antibiotics.

OYVIND ZAHL ARNTZEN/NTB/AFP VIA GETTY IMAGES

Avian flu is of concern due to the risk of it gaining mutations that help it easily infect humans

Has it become harder to communicate public health information since covid-19?
We're still suffering a lot from the pandemic and from the clear examples of misinformation and disinformation that occurred. The whole thing comes back to trust, right? Who can you trust to give you valid, helpful health information? During covid-19, we heard so much contradictory and so much argumentative dialogue about what was good, what wasn't good, who was studying this, where this was in the pipeline, how this was going, that it was really hard to separate the noise from what I think most of us in the traditional scientific field were trying to do.

Scientists don't agree. We review papers, we review grants and we argue – that's what we do. But all of a sudden, it was very much on the outside, and people were seeing that. And I think that paradoxically undermined trust. That unsettled a lot of people who just didn't understand that's how we operate. I don't think we've gotten over that yet.

> "Vigilance is really important or we're going to get caught flat-footed again"

Aside from AMR, what are the biggest public health concerns coming down the track?
I'm obviously worried about influenza, and respiratory viruses in general. Coronavirus and influenza – they've struck twice now, big time, in our relatively recent memory.

The signals for the current situation with avian influenza in dairy cattle, other mammals and wild birds is really concerning, because the more you see mixing and the more you see cross-species transmission, the more opportunity you have for mutations that are going to favour the ability to infect humans.

Would we be equipped for another pandemic?
We have vaccines ready to scale up. But I'm worried, given how quickly covid-19 spread and the toll it took, that we are going to be challenged if this happens again, especially with all the conflict right now. So many people are vulnerable, whether it's for socioeconomic reasons or war. That's what keeps me up at night. I never want to sound too alarmist, but I do think vigilance is really important or we're going to get caught flat-footed again. ▮

Charlotte Lytton is a freelance writer based in London

The back pages

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Stargazing at home

Blazing into sight

A "new" star, T Coronae Borealis, will become visible to the naked eye in the next few months. **Abigail Beall** explains how to spot it

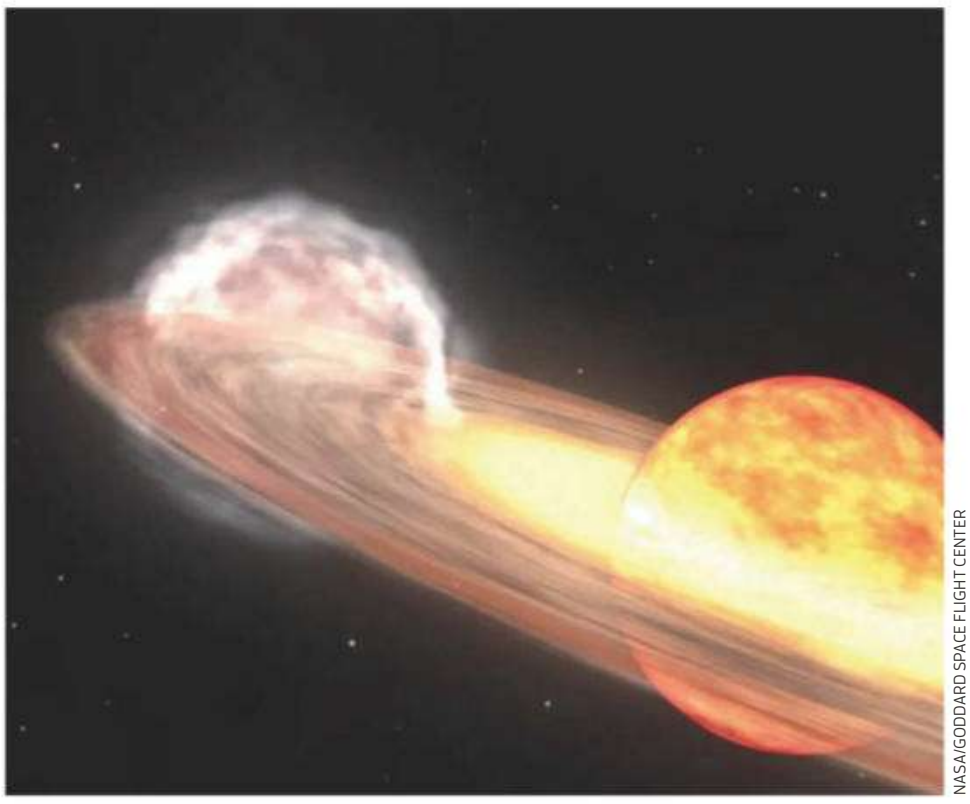
Abigail Beall is a features editor at *New Scientist* and author of *The Art of Urban Astronomy*. Follow her @abbybeall

THIS week we are focusing on what is currently a dark patch in the sky, but won't be for much longer. That's because a "new" star is expected to appear in the night sky over the next few months.

Of course, the star isn't actually new – it has been around for billions of years. What's new is that it will be visible to the naked eye, temporarily, while undergoing an explosive event called a nova.

The object in question, called T Coronae Borealis – or the much catchier "blaze star" – is actually a binary star system made up of a white dwarf and a red giant orbiting each other. The hungry white dwarf has been stealing hydrogen from its companion star by means of its gravitational pull. "Once sufficient material has built up, [it] will reach a critical temperature, igniting hydrogen fusion," says Mark Hollands, an astronomer at the University of Warwick in the UK. "This powerful nuclear detonation ejects the gas from the white dwarf surface in a hot, luminous shell. What we then see is the system becoming thousands of times brighter."

While the exact date this explosion will happen isn't known, astronomers have been watching the system and expect it to be soon. After observing a dip in brightness since March 2023, which happens before a nova, they predict it will occur between now and September. Once it explodes, the system will become almost as bright as Polaris, the North Star, for a few days.



NASA/GODDARD SPACE FLIGHT CENTER

The best way to prepare for the event is to get familiar with the patch of sky the star system sits in. T Coronae Borealis is in a small constellation called Corona Borealis. This sits between Boötes and Hercules, two much larger constellations in the northern sky.

The best way to find Corona Borealis is by first finding two stars: Arcturus, which will be high in the south in the northern hemisphere, and Vega, which will be lower in the sky and towards the east. These are the two brightest stars in the northern hemisphere, so they should be easy to see from there. Looking directly between the two, you should spot a horseshoe-shaped group of stars: this is Corona Borealis. From the southern hemisphere, Arcturus will be low in the north-east. If Vega is visible, it will be near the eastern horizon and Corona Borealis will be low in the north-eastern sky.

When it makes its appearance, the "new" star will be the brightest in the constellation, making it hard to miss. It will appear just below and to the left of the main horseshoe shape. This kind of event doesn't come around often – this star system is one of 10 known repeating novae and it explodes roughly every 80 years.

I hope you enjoy watching the sky change. It is a lovely reminder that the stars aren't fixed points of light as they seem to be, but dynamic monsters that are growing and evolving. ▮

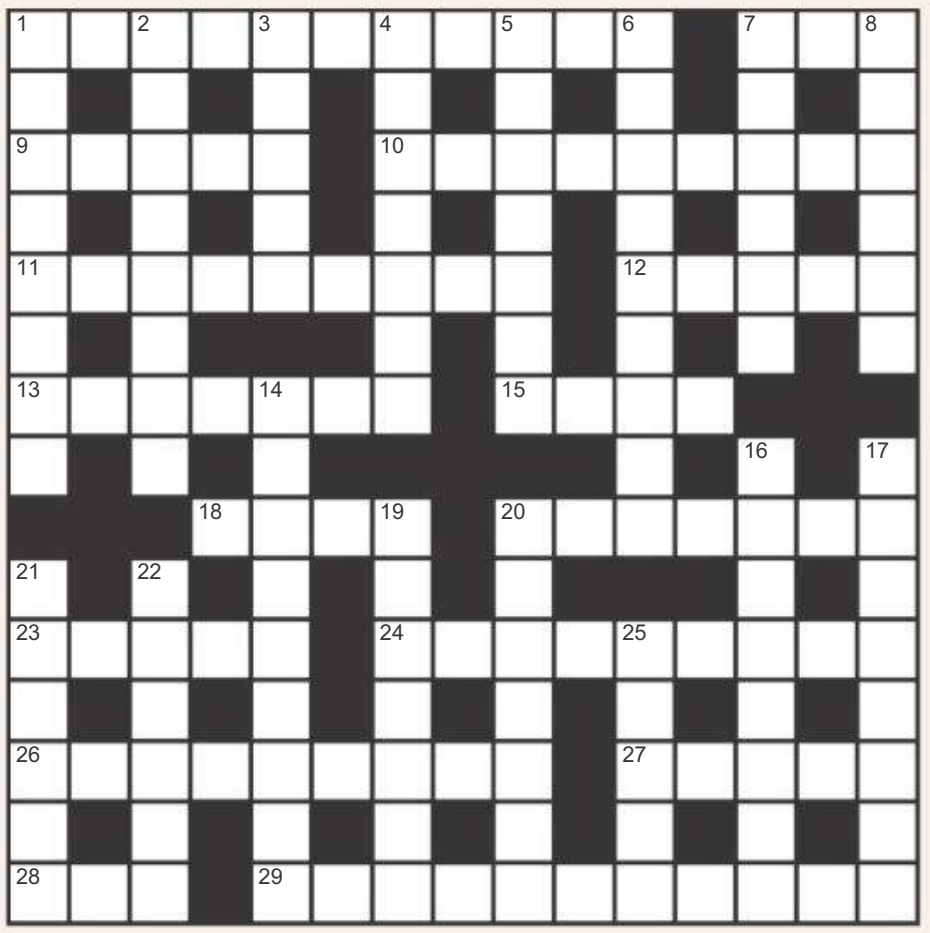
Stargazing at home appears every four weeks. Share your stargazing successes with us on X and Instagram @newscientist, using the hashtag NewScientistStargazing

These articles are posted each week at newscientist.com/maker

Next week

Mathematics of life

Quick crossword #161 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Cholecyst (11)
7 Hannah ___, British mathematician (3)
9 More (5)
10 Widely used desiccant (6,3)
11 Ordinal of 30 (9)
12 Control system of a mechanical device (5)
13 Inflammation in the eye (7)
15 Robust pin (4)
18 Colour of $CoAl_2O_4$ (4)
20 Pointed, with a circular base (7)
23 Incan thread database (5)
24 Nationality of scientists Ivan Puluj and Mikhail Ostrogradsky (9)
26 Very thin (9)
27 Alessandro ___, Italian physicist (5)
28 Carnivorous parrot of New Zealand (3)
29 Stochastic model, in probability (6,5)

DOWN

1 Extinct North Atlantic seabird (5,3)
2 Meshes (8)
3 Modified leaf (5)
4 Fluid-filled swelling (7)
5 Marine mammal (7)
6 Motion away from the observer (9)
7 Shape; number (6)
8 Buttercup colour (6)
14 Te (9)
16 Yarrow (8)
17 Banana-like plant (8)
19 Line at 0° latitude (7)
20 Short-distance audio communication system (2,5)
21 Short high-pitched noise (6)
22 Winged insect that may be periodic or annual (6)
25 Group of microbiology tests (acronym) (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #258
set by Bethan Ackerley

1 Who was the first woman to operate a robotic arm in space?

2 The Linear A script was used by which Bronze Age culture?

3 Which order contains the majority of living bird species?

4 Name the youngest person to receive the Nobel prize for physics.

5 An excessive amount of fat in faeces is known as what?

Answers on page 47

BrainTwister
set by Peter Rowlett
#26 Up and down

Which is bigger, 30 × 30 or 29 × 31?

If we choose a number other than 30 and compare its product with itself to the product of the numbers one above and one below it, which is bigger? Does this always work the same way?

If you choose any two numbers that are above and below 30 by the same amount, what is the difference between their product and 30 × 30?

Solution next week

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Height of change

As average sea levels rise, will contour lines and spot heights on maps need to be recalculated? If so, when?

Simon Ritchie
Leatherhead, Surrey, UK
Height above mean sea level is only one of at least three measures of height. Two others are the height above a perfect ellipsoid that approximates the shape of Earth, and the height above an irregular shape called the geoid, which is another useful approximation of our planet's shape. Modern GPS-based surveying equipment gives your position relative to Earth's centre of mass. That is most sensibly expressed as geoidal or ellipsoidal height or both.

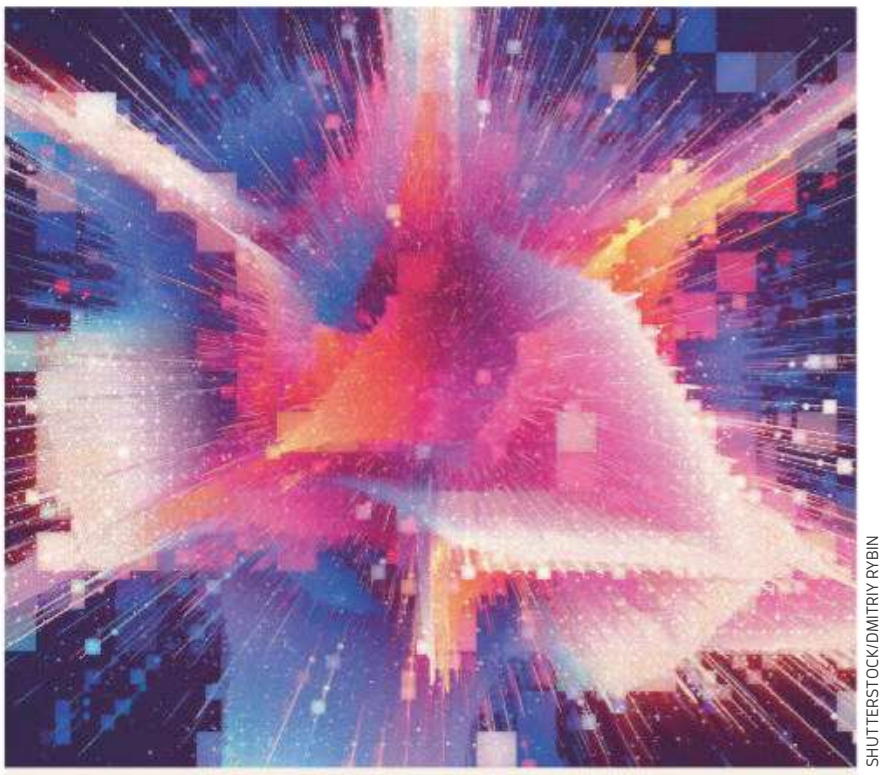
The mean sea level figure for the UK was calculated by mapping agency the Ordnance Survey (OS) in the early 20th century using a facility at Newlyn in Cornwall. For the purposes of making land maps, the fact that the value may no longer quite coincide with the mean level of the sea at that location isn't a big issue.

It is essentially an arbitrary value – you can think of it as

"It is worth mentioning that the meridian line marked on the ground at Greenwich Observatory is in the wrong place"

80 centimetres above the geoid or as 1345 metres below the summit of Ben Nevis. In any case, if the OS did redefine it, the effect wouldn't be visible given a paper map's scale.

It is also worth mentioning that the meridian line marked on the ground at Greenwich Observatory in London to denote the line of 0° longitude is in the wrong place. That is due partly to continental drift, but mainly due to errors in the original calculation caused by factors such as deviations in the direction of local gravity.



SHUTTERSTOCK/DMITRIY RYBIN

This week's new questions

Adding up **Did abstract mathematics, such as Pythagoras's theorem, exist before the big bang?** ***John Woodgate****, Rayleigh, Essex, UK*

Hard hitting **What happens when a hammer hits a nail? Do hammer electrons hit nail electrons? If not, what drives the nail in?** ***Oliver Howes****, Sydney, Australia*

Did abstract mathematics exist in the universe before the big bang?

In a spin

Are humans the only animal to experience vertigo?

David Muir
Edinburgh, UK
Your vestibular system informs your brain about balance, movement and the physical location of your body parts in relation to your surroundings.

This complex set of structures and neural paths is situated in the inner ear. When something goes amiss within the vestibular system due to infection, trauma or drug intake (for instance, alcohol), you might experience vertigo, a sense of spinning and imbalance. Most vertebrates have vestibular systems, but not necessarily similar to that of humans, and various vestibular organs are present in invertebrates. Does this mean that many vertebrates, and even invertebrates, may suffer some kind of vertigo?

Vets describe symptoms of vestibular disease in pets, perhaps implying that they experience vertigo. These symptoms can include staggering, falling over, lack of coordination, head tilt and circling. However, we will need to wait for improved pet-human communications before we can know if this is truly vertigo.

These symptoms can also be exhibited by primates, elephants and me, after overindulgence in fermented fruit or the products thereof, thus compromising the vestibular system.

Mike Follows
Sutton Coldfield, West Midlands, UK
Experiments suggest that young mammals, including human infants, draw back from cliff edges. Thankfully, this is instinctive – and not learned behaviour – otherwise many individuals wouldn't survive

Richard Kay
Coventry, UK
According to the Fifth Assessment Report by the Intergovernmental Panel on Climate Change, sea level rise this century is estimated at between 26 cm and 98 cm.

This rise will be combined with other ongoing natural changes in land elevation caused by glacial rebound, continental drift, seismic activity and changes in water tables due to groundwater extraction, reservoir building and river floodplain management.

Laser and radar altimetry, based on satellite surveys, seem likely to be more accurate, while enabling more regular updates of map contours, when compared with old-school surveying techniques involving measurements using theodolites.

Hillary Shaw
Newport, Shropshire, UK
If land is rising or sinking by a few millimetres a year, in a flattish area where the gradient is 1:500, the contours will migrate by a metre or so laterally per year. Over a few decades, this change would become clear on a 1:25,000 map.

In reality, contours need only be accurate vertically to up to 5 metres at their marked location. This is a NATO standard. NATO is interested in contours because ground-hugging missiles use them for navigation, so I guess civilian maps aren't published with 100 per cent accurate contours either. We would have more worries than redrawing contours should sea level rise exceed 5 metres.

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Tom Gauld
for New Scientist

WE NEVER DISTURB THE PROFESSOR WHEN HE'S THINKING.
YOU'VE JUST GOT TO BE PATIENT: MUCH OF HIS BEST WORK IS THE RESULT OF LONG PERIODS OF QUIET REFLECTION.
SHOULD WE AT LEAST TRIM THE IVY BACK?
YEAH, PROBABLY.

their mistakes. To show this, experimenters used a "visual cliff" (a glass-floored bridge spanning a sheer drop), which mammals were reluctant to venture onto. Sea turtles had fewer qualms, probably because they experience swimming above drop-offs in the ocean with no ill effects.

Obviously, a few individuals suffer from acrophobia, the irrational fear of heights. Given our pampered lifestyle, it is possible that our species tolerates phobias better than other species do, perhaps because it might compromise their ability to compete for scarce resources.

Technically, vertigo is a spinning sensation in the absence of actual spinning, which can be triggered by movement, such as standing up or looking at a moving object.

Height vertigo can occur when looking down from a high vantage point or looking up at a tall object. A difference in pressure (or temperature) detected in the ears can also induce a spinning sensation.

Scuba divers can experience

"Given our pampered lifestyle, it is possible that our species tolerates phobias better than other species do"

this if one ear clears before the other, particularly in chilly water. This can be particularly alarming out in the blue or in poor visibility when there is no visual reference.

Guy Cox
Sydney, Australia

Certainly not if we consider middle ear infections. Years ago, I got a phone call from my son saying that he had accidentally dropped his pet mouse and now it was paralysed. Well, you can drop a mouse from the Empire State Building and it stands a chance of walking away, so it was clear that something else was wrong. I headed home and we took the mouse to the vet. It was a middle ear infection, and the vet's bill far exceeded the cost of the mouse!

Over the edge

Why, if an unfastened duvet cover is put into a washing machine, does it bag up all the other items in there to be washed?

Garry Trethewey
Arkaroola Wilderness Sanctuary, South Australia

It is a stochastic process with a filter. Imagine a modified pool table with 10 balls, oscillating sides and a single pocket in the middle. The balls would move around randomly, but, now and then, one would fall into the pocket. This can give the impression of some sort of intentionality – "the thing that makes balls collect in the pocket".

Your duvet cover is like that. Imagine chucking socks at it from random directions. From the right (for example), they will collect in the bag; from the left, they won't.

Peter Coates
Yukon, Canada

Everyone knows that duvet covers are the apex predators of the washing machine ecosystem. ▮

Answers

Quick quiz #258 *Answers*

1 Sally Ride
2 The Minoans
3 Passeriformes
4 Lawrence Bragg
5 Steatorrhea

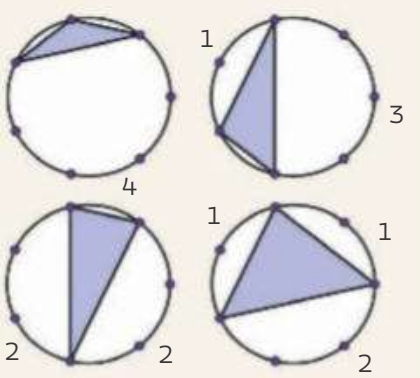
Cryptic crossword #138 *Answers*

ACROSS 1 Ramsons, **5** Awry, **8** Insta, **9** Lactate, **10** Geiger counter, **11** Coffer, **13** Flasks, **16** Food allergies, **20** Antlion, **21** Glaze, **22** Snug, **23** Yellows

DOWN 1 Ruing, **2** Mastiff, **3** Ovate, **4** Splice, **5** Accrual, **6** Roast, **7** Ferris, **11** Caftan, **12** Evading, **14** Stifado, **15** Flinty, **17** Often, **18** Rigel, **19** Specs

#25 Triangles in circles *Solution*

From seven points you can make four triangles, and from 12 points, 12 triangles. There will be either one, two or three groups of unused points, with the groups separated by the triangle's corners; each grouping gives a different triangle. For seven points, there are four unused points, which can be grouped in four ways: (4), (3,1), (2,2), (2,1,1)



For 12 points, nine are unused, which can be grouped in 12 ways: (9), (8,1), (7,2), (6,3), (5,4), (7,1,1), (6,2,1), (5,3,1), (4,4,1), (5,2,2), (4,3,2), (3,3,3).

Hardened children

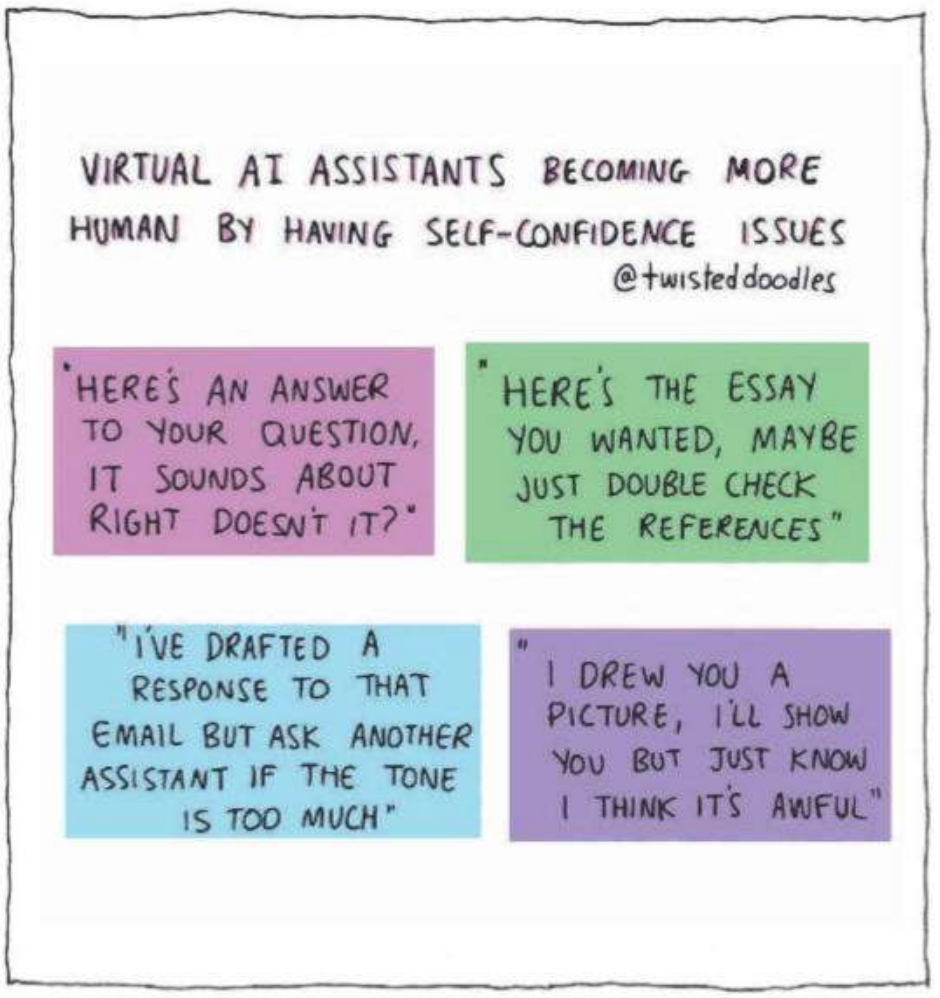
"It is well known that the best means of preventing colds is hardening," writes Sidikova Maryam Amankeldievna in the *Journal of Medicine, Practice and Nursing*. To prevent parents from going overboard, she warns that only healthy children "can be hardened with water procedures".

Hardening may be best, but it isn't the one-and-only method of cold prevention. Amankeldievna, a researcher at Samarkand State Medical University, Uzbekistan, also advocates rubbing. "Rubbing," she specifies, "should be done all year round." Done properly, rubbing "is carried out in the following order: first the arms, then the legs, chest, stomach and back".

Hardening need not be water-based. Amankeldievna also approves of air. "Air hardening is a milder factor," she writes, "and is allowed for children of all health groups."

Sunlight is another alternative. But sunlight hardening is problematic: "Sunbathing," says Amankeldievna, "is possible only with the permission of a doctor."

Twisteddoodles *for New Scientist*


VIRTUAL AI ASSISTANTS BECOMING MORE HUMAN BY HAVING SELF-CONFIDENCE ISSUES
@twisteddoodles
"HERE'S AN ANSWER TO YOUR QUESTION, IT SOUNDS ABOUT RIGHT DOESN'T IT?"
"HERE'S THE ESSAY YOU WANTED, MAYBE JUST DOUBLE CHECK THE REFERENCES"
"I'VE DRAFTED A RESPONSE TO THAT EMAIL BUT ASK ANOTHER ASSISTANT IF THE TONE IS TOO MUCH"
"I DREW YOU A PICTURE, I'LL SHOW YOU BUT JUST KNOW I THINK IT'S AWFUL"

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We all know that

If you are a rapid reader, it is easy to keep abreast of everything that is well known: just read the thousands of new research papers published every week. But not everyone is a rapid reader.

As a service for slower readers, Feedback aims to round up some of the things that – as testified in scientific literature (see above) – are officially well known. Each is documented in a statement that begins "It is well known that...".

Here are some well-known examples.

The forgetful functor is well-known. Cary Malkiewich and Maru Sarazola write in a preprint study: "It is well-known that the stable model structure on symmetric spectra cannot be transferred from the one on sequential spectra through the forgetful functor."

Some really complicated things are well known. Frank Nielsen, writing in the journal *Entropy*, mentions one: "It is well known that skewed Bhattacharyya distances between the probability densities of an exponential family amount to skewed Jensen divergences induced by the cumulant function between their corresponding natural parameters, and that in limit cases the sided Kullback–Leibler divergences amount to reverse-sided Bregman divergences."

Heinz Kohut's papers on narcissism are well known. Allison Merrick, writing in the journal *Psychoanalysis, Self and Context*, reminds us it is "well known that Heinz Kohut's papers on narcissism brought forth a re-evaluation of a patient's healthy self-regard".

Ronald Fagin and Joseph Halpern, in a paper called "A new approach to updating beliefs", note that it is "well known that the conditional probability function is a probability function".

And Luca Di Luzio, Admir Greljo and Marco Nardecchia, writing in *Physical Review D*, assure us that "it is well known that massive vectors crave an ultraviolet (UV) completion".

How many of these well-known things do most people know? The answer to that question is unknown. If you know of a way-too-little-known well-known thing that screams for its moment in the sun, please send it (with documentation) to: Well-known things, c/o Feedback.

The fascist disease

Reader Jennifer Skillen tells Feedback how thinking about thinking led to a mother-son collaboration during one of their shared reading sessions, which began years ago with *The Very Hungry Caterpillar* and now encompass *New Scientist*, along with other more adult material.

"The other day when I started reading the cancer section of 'How to think about...' [*New Scientist*, 25 May, page 42], my son said, 'Mum, how about reading it substituting the word fascist for cancer.' Well, nothing is too much trouble for me when it comes to my son, so I did," says Jennifer.

"Surprisingly, the article read very well with the substitution; it both continued to make sense, but was also very funny. It seems both cancer cells and fascist cells respond to changes in the environment, and can divide rapidly."

Feedback agrees, and provides some snippets from the article so readers can make up their own minds: "Cancer cells compete for access to nutrients, and only the fittest survive... They're evolving to become the best cancer cell they can become and that typically is bad news."

Jennifer and her son have thus been wondering about other word pair substitutions that readers may have found for *New Scientist* articles, where the substitution "makes sense, increases knowledge and amuses".

Eely gross

The question "What's inside?" leads to many a surprise, sometimes involving an eel. Rohit Goel at Pondicherry Institute of Medical Sciences in India and his colleagues reveal one of those surprises.

Writing in the *The American Journal of Forensic Medicine and Pathology*, the researchers describe "a rare example of an interesting postmortem artifact of the presence of moray eels within a corpse".

The team says that to the best of its knowledge, "this is the first reported case of such a finding". ▮

Marc Abrahams

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